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644.

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THE PLANT OF MARITIME COMMERCIAL PORTS OF FRANCE.

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Preliminary Observations.—The questions relating to the plant of maritime commercial ports, which, for a long time, were considered, at least in France, as being of relatively secondary importance, have for some ye taken a commanding place in the attention of all those who are in sted in the development and prosperity of maritime ports, and gr at efforts have been made on all sides to endow French ports with the means necessary to carry on their work in the most rational manner possible.

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The object of this paper is to give a general review of the progress made in this direction, during the last 10 years, in the more recent installations. This rapid review will indicate the principles which, it seems to the writer, should guide in similar works.

It is first of all necessary to define what is meant by the plant of a commercial port. This name is given to the whole group of appliances which, while not indispensable to the existence of maritime traffic, facilitate its operations, render them more rapid and less onerous, or, in a word, ameliorate the conditions of work. In other terms, equipping a port is to get from it the greatest possible amount of essential work, from its basins and its quays, by fitting it out in the most profitable manner.

The capstans which, placed in the wing walls of the locks, facilitate and expedite the passage of vessels; the mechanisms which render the movements of gates and bridges more rapid; the machines which operate the discharge of merchandise; the sheds which shelter it during the loading and unloading; the warehouses where it accumulates; the special arrangements necessary to certain particular classes of commerce—these are some of the appliances which are to-day necessary to the life of a large maritime port and constitute its commercial plant. Perhaps the dry docks in which vessels can be repaired and rendered seaworthy should be added.

A double cause has retarded for a long time in France the complete organization of a perfect plant.

First of all, these individual parts of one whole do not originate in the same source and under one administration; the State Constructor of the Port usually furnishes it with dry docks, and always attends to the lifting engines on the locks; the railway companies construct the tracks on the quays; the Chambers of Commerce, ordinarily, build the sheds and put in motion the machinery for loading and unloading; separate organizations build the warehouses, and, in general, there is no one who can give attention to the special arrangements necessary to draw to a port a special commerce.

This diversity of the powers of many administrations which, nevertheless, should co-operate to one end, entails in practice many difficulties, and, in addition to this, the Constructor of the Port, who should have a primary interest in its proper working, has not the control over the plant which should belong to him. The plant is not only a facility

given to commerce, but it is an element of economy in the hands of the Constructor of the Port, which permits him to double and triple the usefulness of its quays and its terre-pleins, and, consequently, diminish the development of works which are so costly to establish.

Now, it must be recognized that the direct and palpable profit of the plant is not always very great, and that often it is impossible for the different parts which compose it to carry by themselves the expense of their own working, the payment of interest and the liquidation of their cost of construction, and this explains the hesitation of those interested in establishing them; but if this direct profit is sometimes debatable, the indirect benefit is always large, and even if the individual account of the sheds, the warehouses, or the machinery for loading and unloading should not show a profit, their establishment would, nevertheless, have procured to the port which possesses them many compensating advantages which would in the end justify the means.

To these difficulties, resulting from the conditions of administration operating the working of the ports of France, must be added those which are met with in the old ports, where, on the one hand, local habits of long standing have acquired considerable force, and have become difficult to modify, at least suddenly; or, on the other hand, the outlines of the works themselves are not well adapted to methods of work which were not foreseen at the time of their construction. This is the condition existing in the majority of French ports; it is forcible from many points of view, and has contributed not a little to increase the difficulties to be met from the special point of view which now occupies our attention.

To-day most of these difficulties have been overcome almost altogether by reason of the more intimate association which has arisen between the Chambers of Commerce and the State for the construction of new works, and under the spur of the most absolute need which rendered it necessary. It should not be supposed, to be sure, that there does not remain much to be done, and this the more as methods improve, and as needs continually change, but it is nevertheless true that a considerable step has been accomplished and that a glimpse can now be had of the approaching moment when French ports need not be envious in the matter of plant of the most favored among their competitors.

The following table gives the comparative situation, for the principal ports of France, of the development of the tracks, sheds and machinery for loading and unloading in 1884 and 1893, and shows the activity which has been displayed during this period in the improvement of the plant of these ports.

Ports.		Length of tracks on quays. Meters.	Area of sheds. Square meters.	Machines for loading and unloading.					
				Hand or steam.			Less than 3 tons.		
				100 tons and over.	20 to 100 tons.	3 to 20 tons.	Stationary steam.	Floating.	Hydraulic.
Marseilles..	1884.....	18 000	62 800	..	7	4	2	6	39
	1893.....	43 000	82 000	1	8	6	1	7	85
Havre.....	1884.....	20 000	54 000	1	2	8	5	4	..
	1893.....	37 000	108 000	1	3	9	12	9	44
Dunkirk..	1884.....	15 000	.....	..	..	..	..	..	..
	1893.....	35 000	20 500	..	2	1	19	9	(Projected) 21
Rouen.....	1884.....	8 500	.....	..	1	2	13	22	..
	1893.....	25 500	12 000	..	1	2	10	36	15
Bordeaux...	1884.....	14 500	.....	..	..	..	..	..	..
	1893.....	16 500	4 800	..	1	..	24	..	..
St. Nazaire.	1884.....	3 000	8 000	..	3	2	16	7	..
	1893.....	18 000	9 300	..	2	5	15	10	..
Dieppe.....	1884.....	6 000	2 400	..	..	..	..	..	..
	1893.....	10 000	5 300	..	1	4	29	..	..
Calais.....	1884.....	35 000	.....	..	..	3	8	..	..
	1893.....	21 000	23 000	..	1	5	8	..	16

Objects of the Plant.—The functions of commercial ports, of the large ones above all, are complex, and the changes made in commercial habits emphasize each succeeding day the double rôle they play. The growing facilities of communication, which multiply incessantly between the various portions of the globe, have as a natural consequence the drawing nearer together of producer and consumer and consequently the rapid development of transit.

It has become common to-day to say that commercial ports may, from this point of view, be considered simply as supplementary to internal ways of communication (railways and water-ways), and as an integral part of one large transfer station, where the sea-going vessel meets the cars or river craft, and where, even if the method of transport changes, the movement should not be stopped. But in addition to this rôle, the importance of which is increasing, the large ports add a second, not less essential because it affects the large com-

mercial markets like those of Havre or Marseilles; it is that of the bonded warehouse. Certain goods should in fact remain in place and undergo a warehousing, more or less long, waiting until they are sold or until again shipped, either by way of the harbor itself or toward the interior. Large markets, which are necessary to the life of commerce, will not be successful without an accumulation of goods, sometimes large, and the port then plays the part of a vast regulator, holding in its warehouses, at certain epochs, the production of far-off countries, in order to restore it during the rest of the year to the consumer.

This double part played by the ports indicates at once, as should be foreseen, that it is impossible to make general rules and to fix in a precise way what should constitute the plant of a port; it follows that when one of the two characters above indicated predominates, the installations themselves take a different character.

For direct transit operations the quays may be very narrow, discharging cranes and some lines of track, parallel to the quays, well connected with a distributing station, suffice; when the transit operates on goods which must be handled or have a preliminary examination, the terre-plein should become larger and the dépôt areas, either covered or not covered, should be on the same scale; if the goods handled must be bonded in the port, the installations should become more complete, and large warehouses, provided with all the necessary mechanisms, should be erected along the quay.

It seems that it would be at least easy in each port before it takes part, to a greater or less extent, in the divers kind of operations indicated, to specialize the quays, to prepare some for transit, others for storage.

While this is evidently the object which should be attempted, it is not always easy to make a complete distinction; first of all, the same vessels very often bring cargoes whose destination is very different, and such cargoes come more and more in the large cargo-boats, some of which carry to-day nearly 6 000 tons of freight.

In the second place, it is necessary to remember the fact that the number of new basins in each port capable of receiving the largest vessels is generally very limited, on account of the rapid increase in the dimensions of ships, and that it is, therefore, indispensable to arrange these basins in such a manner as to permit them to accomplish the different kinds of operations. It has also been the custom in France, in most of the basins constructed lately, to constitute a plant

which, while defective for transit and for warehouses, permits the quays to render at least the double service which may be demanded of them.

Railway Tracks.—The tracks are the most essential portion of the equipment of ports; the laying of them along the quays, while necessary for direct transit, is also useful for connecting them with the public warehouses and the industrial establishments. For the purpose of an active transit, three lines placed lengthwise along the quay are indispensable, these lines being moreover connected with each other by switches, at distances which do not exceed the length of a vessel, in such manner as to bring empty cars before each discharging vessel and to take away loaded cars without interfering with the operations of neighboring vessels. This plan is the one adopted at Dieppe on the coal dock, where it gives entire satisfaction (Plate I, Fig. 5).

On the new quays of the ports of Marseilles, Havre and Dunkirk, where the transit never reaches the same intensity, it is not necessary to resort to a similar plan.

The tracks at Bellot Basin, at the Port of Havre, are arranged in the following manner (Plate I, Fig. 1):

Along the north quay, of which the terre-plein is 89 m. wide, three groups each of two tracks are arranged. The first group, with track centers at 2.965 m. and 6.83 m. from the edge of the quay, is intended principally for transit operations; the one of those lines which is nearer to the quay is afterwards included between the two rails of a line of cranes; the two other groups are situated on either side of the service road, their center lines being at 57.785 m., and 62.785 m., and at 81.785 m., and 86.425 m. from the edge of the quay.

The first of these groups effects the loading and unloading of goods handled on the terre-pleins, and the second serves as siding and reserve.

Along the south quay, the width of which is 125 m., a similar arrangement of tracks is adopted, with this difference only, that the group of side and sorting tracks can be increased to five tracks as soon as the necessity is apparent.

All of these groups of lines are connected at frequent intervals, and the system has been worked out with the intention of permitting entire trains on all parts of the lines. The use of turn-tables has been absolutely prescribed, a sorting platform placed at the extremity of the basin is connected with the service lines of the quay by curves accessible to the largest rolling-stock in use on the French system, the

smallest radius allowed on the road being 125 m. For serving the short quays which separate the two tidal basins of the Bellot Basin, curves of 60 m. radius have been used, in order to avoid putting in turn-tables.

The arrangement of the lines of track of the Freycinet Basin at Dunkirk is somewhat analogous to that of the Bellot Basin, but the plan of the inclined tidal basins lends itself in a very happy way to a convenient operation by railroads (Plate I, Fig. 3).

The lines which operate each pier-wharf are five in number and include a group of two lines, the centers of which are at 3.25 m. and 10.75 m. from the edge; a second group of three lines is placed back of the sheds. The number of lines of these two groups can be made respectively three and five if that becomes necessary.

As all the tracks are connected by switches to the lines of the distributing station, approximately 140 meters are managed by right-angle connections, by means of turn-tables.

In the new wet dock of the Port of Calais (Plate I, Fig. 4) the system of tracks operating the quays has been considerably developed by the *Compagnie du Nord* with the hope of attracting to the quays of that port an important transit. On the West Quay two lines are placed along its edge, and a group of five lines is placed in the rear of the distributing platform of the freight depot. On the East Quay the number of tracks placed along the edge of the quay is now three. The two groups are connected from place to place by cross-overs furnished with turn-tables, but all their parts are, nevertheless, accessible to complete trains which travel only over curves of large radius.

The quays of the Port of Marseilles, which allow, also, a considerable development of tracks, are laid out on lines at right angles, which are less favorable to railway communication than those of the Freycinet Basin; the quays of the old basins (Arene and Lazaret) only communicating by turn-tables with the tracks of access to the maritime station. This plan, notwithstanding the use of hydraulic capstans, which, while lessening the inconvenience, are certainly less favorable to large freight movements, also without renouncing meanwhile the use of turn-tables (which in all the Mediterranean are regarded with a favor difficult to explain) has been arranged in such a manner as to connect by curves of large radius the tracks which operate the pier-wharfs of the Gare Maritime and National Basins with the maritime stations (Plate I, Fig. 9).

On the piers each quay is operated by three railways, one of which is placed near the edge of the quay, and the other two in the center of the pier, where there is, therefore, a group of four connected tracks. On the Pinède, which is reserved for mineral ores and coal, the number of tracks is five, divided into two groups, one of three tracks placed along the edge of the quay, and another of two tracks at some distance in the rear; these two groups, being connected by frequent right-angle communications provided with turn-tables.

The three important maritime and sorting docks, which at Marseilles are parallel to the general direction of the port, permit, as a consequence, the tracks of the quays to be easily served, and from this point of view, as from many others, the plant of this large port is worthy of the foremost French harbor.

The conditions at the Port of Rouen, where the quays spread out all along the Seine, and do not allow of basins, differ from those of the ports which we have just reviewed; the tracks which serve its quays extend along on each bank, not the least difficulty being encountered in their construction. On the north bank of the stream, three tracks, connected with groups of distributing tracks, run parallel to the quay, a single track is placed near the edge, and the other two in the rear of the terre-plein; on the south bank, two tracks run along the edge of the quay, and a single one is placed in the rear of the terre-plein.

If the development of these tracks is on a smaller scale than that of some of the ports before cited, it is due to the commanding place occupied at Rouen by the river boating, which performs the largest part of the transportation towards the interior.

Sheds.—In almost all the ports of France, the construction of sheds, intended to shelter goods during their stay on the terre-pleins, has been greatly developed; the regular lines of navigation receive in the interval between the times of departure merchandise for export, often valuable, which must sometimes be held, awaiting the departure of the next packet; for such goods the shed is an absolute necessity. While less necessary for imported cargoes, which can in general be shipped rapidly towards their destination (fluvial lighters, cars or warehouses), the sheds render, nevertheless, important service in accelerating the operations of unloading, which, by their use, are not interrupted by bad weather.

To render all the service for which they are intended, the sheds

should be at a short distance from the edge of the quay, and it should be easy to close them. In almost all French ports the distance from the face of the sheds to the edge of the quay is from 10 to 12 m., and provision for closing the sheds is everywhere made, except at Rouen, where the sheds play only the part of umbrellas

At Havre the Chamber of Commerce has established a large number of sheds, which are much appreciated by commerce; the quays of the west dock of the Bellot Basin, in particular, have been furnished with sheds on almost all of their area (Plate I, Fig. 1).

On the North Quay three sheds 45 m. in width are built, overhang not included, the lengths of which are respectively 77.5, 139.5 and 93.0 m.; on the South Quay are also erected three sheds, of 55 m. width and of 80, 160 and 180 m. length. These sheds are separated from each other by open spaces of 40 m.; this break in the shelter is for the purpose of diminishing the chance of conflagration, to reserve on the quays parts of the terre-pleins for cumbersome merchandise and heavy weights, to reduce the expense of the installation by not erecting anything on the unused spaces which are found between two vessels, and, finally, to allow trucking to be easily carried on on the quay without traversing the sheds. The sheds have metallic frames with roofs of zinc plates, exterior walls of brick, all of the face situated on the side towards the quay being made up of movable doors (Plate III, Figs. 1 to 26).

The number of supports has been reduced as much as possible consistent with an economical construction, in order to present the least obstacle to the circulation of vehicles and to the piling up of goods; thus the sheds of 55 m. width are composed of trusses in 2 bays of 27.5 m. span, and 10 m. center to center. The principal dimensions of these buildings are summed up in the following table:

Sheds.	North. Meters.	South and West. Meters.
Span of rafters	22.50	27.50
Spacing of rafters	15.50	16.00
Total height of shed	11.64	12.60
Total height of doors	4.75	4.75
Number of intermediate rafters	2	....
Purlins	T iron.	Lattice.
Height of purlins	0.16	0.60
Least spacing of purlins	1.60	1.75

The net cost of the north sheds varies between 34 and 40 francs per square meter, not including the general charges for design and superintendence, which may be placed at 3 francs per square meter. The net cost of the south and west sheds, the spans of which are larger, has been nearly 42 francs, not including the general charges.

The cost is established by the square meter of covered surface between the sides of the sheds, that is to say, it does not include the surface covered by the overhang.

The net cost of the cheaper sheds can be itemized as follows:

		Francs.	Francs.
Superstructure.—	Foundations	.....	2.00
	Metallic frame	14.58	
	Roof	5.71	
	Battens	2.88	
	Gutters and leaders	0.88	
	Painting and glazing	0.27	
			24.32
Lateral Closing.—	Metallic frame	1.60	
	Wainscoting	1.51	
	Hardware for doors	1.23	
	Painting and glazing	0.48	
	Masonry	1.34	
			6.16
Miscellaneous.—	Drains	0.39	
	Paving of entrances	0.24	
	Lighting	0.23	
	Miscellaneous	0.66	
			1.52
	General charges		3.00
			37.00

The sheds built at Marseilles, Calais, Dunkirk and Dieppe are of about the same type as those adopted at Havre and present the same general arrangement.

At Marseilles the sheds of the Chamber of Commerce are 38 m. in width, divided into two equal spans: those of Calais are 40 m., equally divided into two spans; those of Dunkirk and of Dieppe have only one span, the length of which is 30 m. for the former and 24 m. for the latter. It is nevertheless necessary to describe the sheds which the Dock Company have recently established at Marseilles on the quays of the Lazaret Basin, and which carry a floor. The construction is made up

of trusses of 24 m. span of which the ridge is 13.05 m. above the ground. A floor placed at a height of 5 m. is supported by cast-iron columns spaced 6 m. center to center; an exterior gallery 3.60 m. wide runs at the level of the floor of the first story to receive goods which are deposited there by the hydraulic cranes (Plate II, Fig. 9). This arrangement, which has the inconvenience of incumbering, to some extent, the ground level with many supports, is, however, advantageous for narrow quays in that it doubles for them the surface which can be used for the storage of goods.

The shelters which the Chamber of Commerce of Rouen established some years ago differ from the general type on which the sheds have been constructed in the ports which have just been reviewed, in their mode of construction as well as in the absence of lateral closing which has been adopted in other ports. The roof is supported by small rafters of 5 m. span running perpendicularly to the quay and resting on longitudinal lattice girders 0.5 m. in depth; these girders are placed on plate supports 6 m. in height and spaced 10 m. center to center (Plate III, Fig. B5). All around the outside of the shed runs an overhang of 4.5 m. width. The sheds on the right bank thus cover a width of 26.2 m. including the overhang, and those on the left bank 34.2 m. including the overhang.

At Bordeaux, the Chamber of Commerce has erected on the quays of the Garonne pavilion-shelters of relatively small dimensions, 20 m. in depth by 30 m. in length. The rafters which support the roof have only 10 m. span and are 3.75 m., center to center. These shelters, of small dimensions, are useful in mild climates, since it is only necessary to shelter very costly merchandise. The following table indicates the net cost of the sheds at Havre, Calais, Dieppe, Rouen and Marseilles which were built at about the same time:

		Cost per Square Meter. Francs.
Marseilles.—	Sheds 38 m. wide	49
	" 25 m. "	50 to 57
Havre.—	Sheds 45 m. wide, with spans of 20.5 m.	37 to 40
	" 55 m. wide, with spans of 27.5 m.	45
Calais.—	Sheds 40 m. wide, with spans of 20 m.	43
Dieppe.—	Sheds 24 m. wide, with spans of 24 m.	43
Rouen.—	Sheds 34.2 m. and 26.2 m. wide, with spans of 25.2 and 17.2 m.	32

Tariffs of the Sheds.—The use of sheds and shelters established by the Chambers of Commerce on the quays of the various French ports allows the collection of a special tax designed to pay for the service rendered. In certain ports, such as Havre, Marseilles, etc., the taxes for use are the only resources which the Chambers of Commerce can place against working expenses, payment of interest and liquidation of the first cost. In others, such as Dunkirk and Rouen, the Chambers of Commerce collect in another way. A tax is levied on all ships which enter the port, whether they use any part of the plant or not. This tax, which is 0.1 franc at Dunkirk and 0.15 at Rouen, permits the reduction of the charges for use.

The determination of the method of levying these taxes has given rise to many differences, and there has been some trouble in finding a method which, while protecting all interests, satisfies in all respects the conditions of a rational rate, and also the exigencies of practice. A uniform method is not in use in the different ports.

For locations by the year made to regular companies the problem is easy, and it is sufficient to have a tax paid which is proportionate to the space occupied. The difficulty exists only for the establishment of an assessment for the use of sheds occupied by transient shipping.

At Marseilles and at Dieppe the tax is in proportion to the number of tons* of goods stored under the sheds. At Marseilles it is 0.5 franc per ton of 1 000 kg., and gives the right to a stay of 12 days under the shed, after which the tax becomes prohibitory and is calculated at the rate of 0.5 franc per ton per day during the first three days, and of 1 franc per ton for each following day. At Dieppe the tax is 0.08 franc per day per ton during the first three days and 0.09 franc per day per ton during the fourth, fifth and sixth, and 0.01 franc during the following days for goods of the first class (cereals, grain, coffees, sugars, cotton, wood); these charges are made respectively 0.1, 0.11 and 0.12 franc for other goods.

At Dunkirk and Calais the tax is also based on the quantity of goods stored, but it is computed from the chartered tonnage; it is at the rate of 0.06 franc per ton per day of the regulation stay, when this does not exceed five days, and 0.12 franc for each day after that for five days within the limit of the regulation period; 0.03 franc for each

* The ton used throughout this paper is the French *tonne* of 1 000 kg. or 2 204 lbs.—*Trans.*

day computed from the expiration of the regulation period during the first twenty days, and of 0.10 after the twentieth.

At Rouen the area of the sheds occupied regulates the tax, which is 0.05 franc per square meter during the first three days, and 0.15 franc during the three following days, and 0.2 franc after that.

At Havre the tax for occupation is based on the size of the vessel which is placed in front of the shed. The tax being otherwise variable in proportion to the width of the shed. It is paid by the vessel according to the tariff given below.

Size of shed.	Tax per day per net gauged ton.	
	Steamers.	Sailing vessels.
	Francs.	Francs.
Sheds wider than 45 m.	0.09	0.075
" from 30 to 45 m. wide	0.08	0.065
" less than 30 m. wide	0.07	0.050

After the departure of the vessel the goods should be removed within a period of three days, after which a storage of 0.05 franc per day during the first five days, and 0.1 franc during the five following days, and 0.2 franc after 10 days, must be paid.

The mode of assessment adopted at Marseilles, Dieppe, Calais and Dunkirk has this great advantage: that the tax is in proportion to the service rendered, and each interested party knows in advance exactly the sum he will have to pay for the sheltering of his goods.

The method in use at Rouen is equally satisfactory from the point of view of the proportionality of the tax to the service rendered, and also that it incites those interested to occupy the least possible space with their goods. But it has one real inconvenience; those interested do not know in advance the sum they will have to pay, as this sum depends upon the manner in which the merchandise is stored under the sheds. It has an element of uncertainty which it would be better to avoid.

It should be stated that both methods of proceeding have a common inconvenience in the practical collection of the tax. To fix the amount it is necessary to make a measurement or a survey, sometimes long, whether it is to determine the volume and the weight of the goods, or the space occupied. It may also give rise to contest, and

this necessitates in all cases on the part of the agents of the Chamber of Commerce a work which may become very long and laborious if there are a great many claimants; it is to avoid these inconveniences that, at Havre, the gauged tonnage of vessels has been established as a common basis for the tax. The amount of the tax is thus easy to establish without possible contest and without any measurement whatever; the gauged tonnage being proportionate, at least very nearly, to the size of the vessel, the tax thus determined is sufficiently proportionate to the service rendered.

Machinery for Loading and Unloading.—The necessity of placing on the quays of ports machinery for loading and unloading is manifest. Sailing vessels do not possess windlasses which will allow them to discharge their goods economically, and the windlasses on which the steamers depend are not adequate to place on cars the goods which they can discharge upon the ground, and there are sometimes heavy loads which cannot be moved by the means on board.

These machines for loading and unloading, the number of which increases rapidly with the large demands of commerce, are of various kinds. On the one hand they can be fixed, movable on rails, or floating on the water; they can be worked by hand, steam, hydraulic power or electricity.

Hand cranes are to-day almost abandoned. There is no motive for their use except for tools of small power, the utilization of which is very rare. Fixed cranes, which oblige the vessel to move, are equally inconvenient and can only be allowed for extremely powerful engines, the first cost of which it is necessary to limit. The general desire is to have in the largest possible measure movable cranes of great power.

In all the large French ports there are to-day tools able to lift the heaviest load. At Marseilles there are nine engines which can lift packages of more than 20 tons; among them are found a stationary oscillating shears of 120 tons, worked by hydraulic power, and many pontoon steam derricks of which the strongest has a capacity of 60 tons. At Havre the number of machines of like power is more limited; there are only four, among which should be mentioned one stationary steam derrick of 100 tons and one floating oscillating derrick of 30 tons.

St. Nazaire, on account of its important ship-building yards, is equally well equipped from this point of view. There are found on its quays two fixed steam shears of 80 tons and one of 40 tons.

At Dunkirk the most powerful machine for discharging is one steam pontoon crane, pivoted, and of 40 tons power.

Machines of great power, nevertheless, are the exception, and most of those for loading and unloading are of a power varying between 1 000 and 2 000 kg., because almost all the packages which make up the ordinary cargoes are of a relatively small weight, and there is no advantage to be gained by assembling a large number of packages to make up each load.

Cranes, properly so called, which allow the placing of goods on the ground at a certain distance from the quay, or on cars, are the most useful and the most generally employed. Windlasses whose net cost is very much less are, however, also used, and in certain cases give good service.

The choice of the system of cranes to adopt for the plant of a port depends on very diverse and complex considerations. Floating pontoon cranes are very advantageous for ports where mechanical handling is little developed, and it is necessary to serve a long stretch of quays with a small number of machines. They offer advantages equally valuable when direct transfers from vessels to lighters are frequent, because they then allow the working of the ship on both sides; their employment becomes on the contrary troublesome in ports where the plant has been well developed, and is also very difficult with large vessels, which are frequent to-day, in harbors subject to violent wind squalls, as the pontoons then suffer from being placed between the ship and the quay.

At Rouen, an interior harbor sheltered from heavy winds, and where fluvial transfers are of great importance, the use of floating cranes is easily justified and they form a most important part of the plant.

The floating-pontoon crane is therefore always an indispensable complement of all well-considered plants; there are always in fact in any port quays which are not furnished with stationary machines, and it is necessary that the lack of them should be supplied by means of a floating crane.

The movable crane on rails seems to be more generally employed, but the motors in use differ; up to the present time in practice, in France at least, only hydraulic and steam cranes are used; many studies of electric cranes have been made, but it is not yet believed

necessary to return to them. The house of Bon & Lustremant has presented for the Port of Dunkirk a very interesting type of electric crane (Plate IV, Fig. 13), but for economical reasons the preference was given to a hydraulic plant.

The only example of the use of electricity for machines for loading and unloading is found at the docks of Havre, where small elevators run by this force are used to discharge grain in bulk.

The use of hydraulic power to actuate machines for loading and unloading is to-day very general and offers great advantages; all the apparatus of the plant is always found in working order at all hours of the day or night without preliminary kindling, the operation is simple and does not offer any danger of conflagration. Finally, from a single installation the cranes, capstans, gates or bridges can be operated. In cold countries some difficulty is found in working the cranes during the winter, but with trifling precautions, too numerous stoppages are, however, avoided.

Recourse has been had to hydraulic power in the recent installations at Calais, Dunkirk, Havre, Marseilles and Rouen. The movable steam crane is not altogether abandoned; it is necessary to resort to it in ports of less importance, which do not require a hydraulic plant, which is always costly, and also in ports operated by hydraulic machinery on such quays as are too distant from the machinery.

Hydraulic cranes are often placed on frames, in tunnel form, under which a railroad track can run, in order to economize space. This is the solution which has been adopted at Havre (Plate IV, Fig. 1). The only inconvenience which results is a slight additional expense for the construction of the crane, and a little greater difficulty in moving it.

At Havre the circulating crane track is composed of two rails placed respectively at 0.80 and 1.90 m. from the edge of the quay. The first of them, which is fixed on the granite, is a flat rail 0.1 m. wide and 0.03 m. thick, the corresponding crane wheel having double flanges; the second rail is placed on a longitudinal beam supported by cross-pieces, spaced 2 m. center to center. It has the form of a ⌐¬ iron 0.10 m. wide, 0.04 m. high; the face of this iron is at the level of the paving, so as not to be an obstacle to circulation; the corresponding wheel of the crane is an ordinary wheel without flanges.

The principal dimensions of the cranes are as follows:

Kind of Crane.	Speed of lifting loads.	Speed of orientation of crane.	Run of hook.	Height of center of block.	Reach of crane.	Angle of orientation.
	Meters.	Meters.	Meters.	Meters.	Meters.	Degrees
Hydraulic cranes of 1 250 kg	1.00	1.25	14.00	12	8.35	360
Hydraulic cranes of 3 000 kg	0.75	0.75	14.00	13	8.35	360
Steam cranes of 1 500 kg	1.00	1.25	16.00	12.60	11.60	180

The hydraulic canalization is composed of two conduits, one for water under pressure, the other for the return of water used; the pressure conduit is 0.1 m. in interior diameter, and the return conduit 0.125 m. The intakes are arranged in the rear of the edge of the quay; they are 12.50 m. distant center to center, and communicate with the general conduit by pipes of 0.02 m. diameter. The connection between these intakes and the lifting engines is made by means of flexible pipes which allow the cranes to be placed in any position whatever on the circulating track.

On the quays of the dock basin, the dock companies utilize, in preference to cranes, hydraulic windlasses; these machines, which are very easily handled, serve not only for the discharge of vessels, but for handling in the warehouses when the direct trans-shipment to cars is not made at the docks, and the parcels discharged are of a small enough weight, which condition is favorable to the exclusive employment of windlasses.

At Marseilles the Dock Company, as well as the Chamber of Commerce, has adopted hydraulic cranes for operating the quays equipped by them, to the almost complete exclusion of windlasses; the same is also the case at Calais and at Rouen.

The machines of these different ports are similar to those of Havre, and the type of frames in tunnel form is almost universal. This type has also been adopted at Havre for steam cranes on the coal quay for the same purpose of economizing the terre-plein.

What is the efficiency that it can be hoped to obtain from machinery for loading and unloading which has been placed on the quays of the ports, of which we have been speaking? This is a very important question; for as soon as these machines are established, a much higher

efficiency is expected than that attained in practice. The following table shows the efficiency based directly on the unloading in progress, the report being made without prejudiced anticipation in order to have results approaching the truth as nearly as possible :

Kind of Machine.	Goods.	Minimum Speed.				Maximum Speed.			
		Number of slings per hour.	Number of packages per sling.	Weight of package. Kilograms.	Tonnage discharged per hour. Tons.	Number of slings per hour.	Number of packages per sling.	Weight of packages. Kilograms.	Tonnage discharged per hour. Tons.
Hydraulic cranes of 1 250 kg. power	Cotton...	54	2	200	21.60	..	..	..	..
	Nickel ore	26	1	1 000 (Net.)	26.00	..	..	..	..
	Corn in sacks...	45	9	62	26.97	..	..	..	..
	Flour in sacks...	56	6	100	33.60	..	..	..	..
	Tobacco..	54	1	380	20.58	..	..	..	..
	Wine	38	2	550	41.80	..	..	..	..
Hydraulic windlasses of 900 kg. power (Dock Company).....	Mahogany logs.....	14	1	1 200	16.80	..	..	..	..
	Coffees. ..	45	10	60	27.00	65	10	60	39.00
	Corn in sacks...	38	1	65	25.00	55	10	65	36.00
Steam cranes { Rolling... Floating..	Coal.... .	32	1	1 000	32 00	48	1	900	43.00
	Logwood	48	1	300	14 40	..	..	..	..
Electric elevation for grain in bulk..... {	Oleaginous grain	7 666	Buckets of 3 kg.		23.00	11 700	Buckets of 3 kg.		35.00
	Corn.....	7 500	" " 4 "		30.00	11 500	" " 4 "		46.00

The unloading can then be operated with the machines for that purpose in use at Havre, at the rate of 20 to 45 tons per hour per hatch, according to the kind of goods, which speed is satisfactory for the most urgent cases. Thus, a coal-boat having three hatches can expect to unload from 1 000 to 1 200 tons in a day of 10 hours' work. A large grain-boat discharging through four hatches can unload from 1 000 to 1 400 tons per day of 10 hours' work, and a cotton-boat with three hatches can unload 3 000 bales per day. For this last-mentioned goods, this result is not generally accomplished in practice, the unloading being retarded by the incumbering of the quay, due to the weighing and sampling of the bales.

The installation of machinery for loading and unloading on the quays is troublesome enough, and it is very rare, except in certain

particular establishments, that the return derived from the placing of these machines pays the costs of working as well as those of interest and the liquidation of capital. This it would certainly do if the use of the machines were continuous, but the fact is that a large number of vessels prefer to use the steam windlasses on board, and consequently the quay engines are often unemployed. In many ports the deficit in the account of the machinery for loading and unloading is covered by a general tonnage tax levied on navigation; in others, as, for instance, Havre, it is covered by the benefit derived from the use of the sheds.

The ordinary cranes are let generally by the hour or by the day, while the unloading of large packages is paid for by the ton. At Dunkirk and Dieppe all unloading is, however, paid for by weight.

For hydraulic cranes the tariffs in force are as follows:

Kind of Cranes.	Rent by the Day.			
	Marseilles. Francs.	Havre. Francs.	Rouen. Francs.	Calais. Francs.
Cranes of 1 250 kg.	32 per day of 8 hours / 40 " " 10 "	25	20	..
" 1 500 "	36 " " 8 " / 45 " " 10 "	30	..	40
" 3 000 "	48 " " 8 " / 60 " " 10 "	45	..	..
" 5 000 "	.....	..	..	70
" 10 000 "	.....	..	..	180
" 20 000 "	.....	..	..	190
" 40 000 "	.....	..	..	200
Shears of 120 tons..	240 per day of 8 hours / 300 " " 10 "	..	..	..
Windlasses of 750 kg.	20 " " 8 " / 25 " " 10 "	18	..	25
" 1 000 "	.....	20	..	..

For the public steam cranes the charges per day are as follows:

Kind of Crane.	Rent by the Day.		
	Havre. Francs.	Rouen. Francs.	Bordeaux. Francs.
Cranes of 1 250 kg., Floating	30	30	..
" 1 500 " Rolling	50	..	50
" 1 500 " Floating	..	..	..
" 10 000 " Floating	100	..	..

The taxes levied on dischargements paid by the ton are as follows for packages of small weight:

	Rouen. Francs.	Dieppe. Francs.	Dunkirk. Francs.
Oils, minerals, etc	0.40	0.325	from 0.75 to 1.25
Other goods	0.60	0.575	

For large packages the prices are as follows:

At Dunkirk the price per ton discharged varies from 3 to 9 francs when the packages weigh from 10 to 40 tons.

At Rouen it varies from 2 to 10 francs, as the weight of packages varies from 3 to 30 tons.

At Marseilles and at Havre the large number of machines of great power brings a competition, and the price varies according to circumstances and the law of supply and demand.

Warehouses and Storehouses.—The warehouses and storehouses which are found in French ports are handled by independent companies which are not connected with the administration of the port. These establishments are generally situated outside of the terre-pleins, and, in consequence are in a less favorable condition for use, a more or less troublesome transport being necessary to carry to them the goods discharged on the quays. The State does not concede the right for a long term to parts of the maritime domain except after lengthy formalities which often discourage the construction of warehouses on the quays.

Nevertheless, at the ports at Marseilles and Havre, there are dock companies, to which the State conceded certain lengths of quay, and which operate them. These companies have, since that time, been able to complete their storehouses under very favorable conditions on the very edge of the quays. In other ports, as, for instance, Bordeaux and Dieppe, the Chambers of Commerce have obtained in the same way the concession of certain parts of the terre-plein on which to erect storehouses.

The Dock Company at Marseilles, to which the State has conceded a length of quays of about 2 500 m., in the Joliette, Lazaret and Arene basins, was organized in 1854, and has remained the most important of the companies of this class in France. In 1892 these sheds and ware-

houses covered an area of more than 220 000 sq. m., which are distributed as follows:

Location.	Sheds. Sq. m.	Warehouses.			Total. Sq. m.
		Cellars. Sq. m.	Ground floor. Sq. m.	Upper floor. Sq. m.	
On the State Concession.....	27 600	.....	44 700	59 800	104 500
On the Company's land.....	.....	9 490	21 100	57 000	87 590
Total.....	27 600	9 490	65 800	116 800	192 090

For many years the Dock Company of Marseilles utilized water under pressure for all its loading and unloading, and its hydraulic plant was the first one in France. The company operates on the quay 53 hydraulic cranes, of which 17 have double power of 1 000 and 3 000 kg., 16 of 1 250 kg. power, and 22 of 1 000 kg. It possesses, besides, one steam crane of 20 tons and one floating elevator for the discharge of grain.

The traffic which is concentrated on the concession of the Dock Company of Marseilles is large, and its example shows well the benefit which a private company can derive from the operation of the quays conceded to it.

At Havre there is also a dock company, organized at about the same time as that of Marseilles, to which the State has conceded the possession of the dock basin, and of the south side of the Vauban Basin, that is to say, a length of 1 650 m. of quay for a period of 99 years.

The warehouses and establishments of the company are developed on the border of the quays, and have a capacity of from 150 000 to 180 000 tons of goods. In 1892 they covered the following area:

Sheds. Sq. m.	Covered Yards. Sq. m.	Warehouses.			
		Cellars. Sq. m.	Ground floor. Sq. m.	Upper floor. Sq. m.	Total Sq. m.
34 700	39 000	8 300	61 200	115 300	184 800

The plant of the company consists of 14 hydraulic windlasses of from 400 to 900 kg. capacity, used as much in discharging vessels as for handling in the storehouses, and of three grain elevators, with chains of buckets, operated by a generating dynamo worked by a 25 H. P. machine. These small movable elevators are easily placed on the point occupied by the vessels to be unloaded and permit their rapid and economical discharge.

At Havre, as at Marseilles and other ports, there are also many private storehouses, located far from the quays, to which they are connected by tracks. These warehouses are indicated in the following table:

	General Storehouses. Sq. m.	Pont Rouge Docks. Sq. m.	Raverat Storehouses. Sq. m.	Briquet Storehouses. Sq. m.
Ground floors.....	7 000	42 000	11 000	7 000
Upper floors	23 000	10 000	6 000	.....
Total	30 000	52 000	17 000	7 000

The Chambers of Commerce are beginning to try to give to commerce the advantages which appertain to docks established on the very border of the quays.

Thus, at Bordeaux, the Chamber of Commerce obtained in 1878 the concession for dock-warehouses occupying an area of 55 000 sq. m., at the very edge of the wet basin. The structures which it has already erected comprise one storehouse for wool, which covers an area of 13 500 sq. m., with cellars for storing wines and alcohol, and a large metallic building 380 m. long and 35 m. wide divided into two longitudinal parts, one used as a dépôt for goods which have settled the custom-house duty, the other for actual bonding. At Dieppe, the Chamber of Commerce has already received the concession of 6 000 sq. m. of ground near the new wet basin, in order to erect general storehouses, the operation of which has since been granted by the Chamber of Commerce to a private company.

Conclusion.—In the peaceful contest which all maritime nations maintain to-day to insure to their ports commercial supremacy, one of the indispensable weapons is the possession of a perfect plant, which,

Fig 1. PORT DU HAVRE

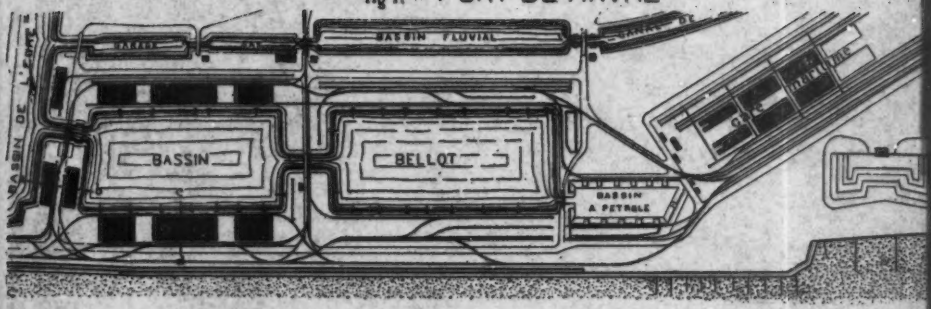


Fig 2. PORT DE ROUEN.

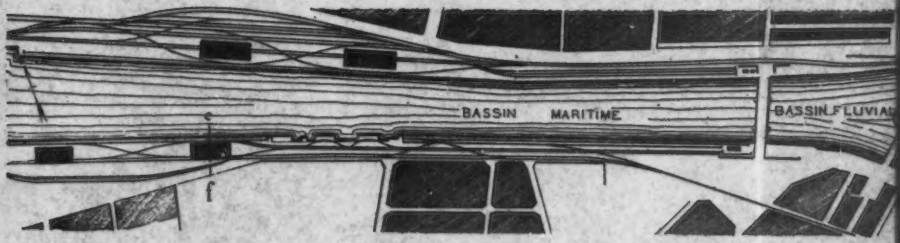


Fig 3. PORT DE DUNKERQUE

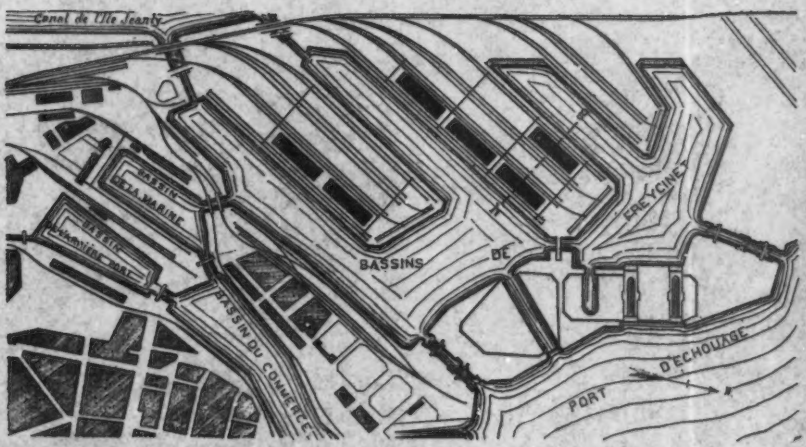
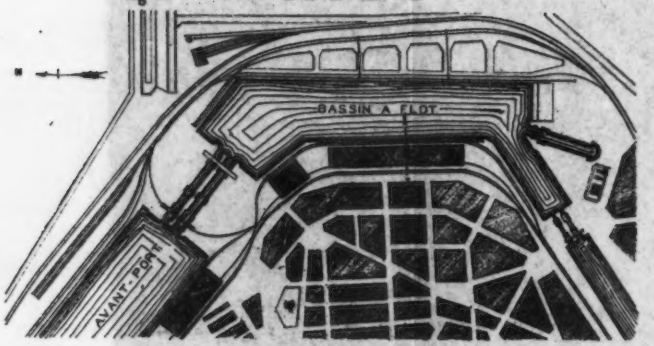
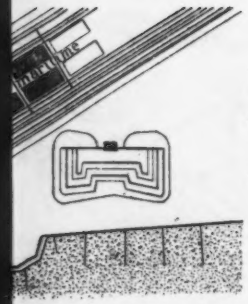


Fig 4. PORT DE CALAIS.





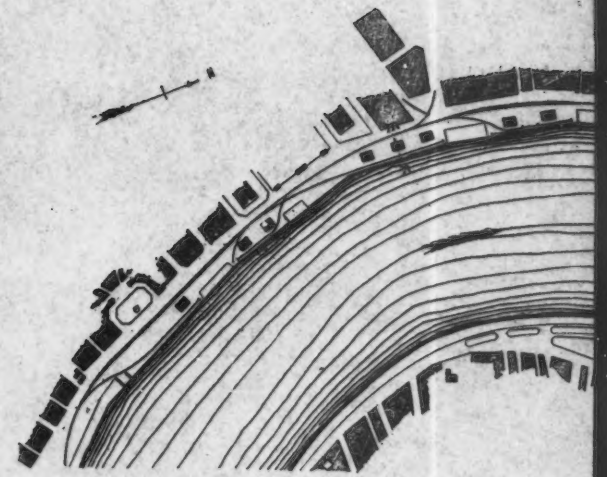


Fig 5.

PORT DE DIEPPE.

Fig 6.

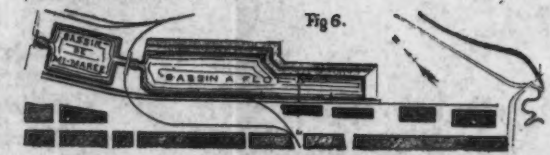
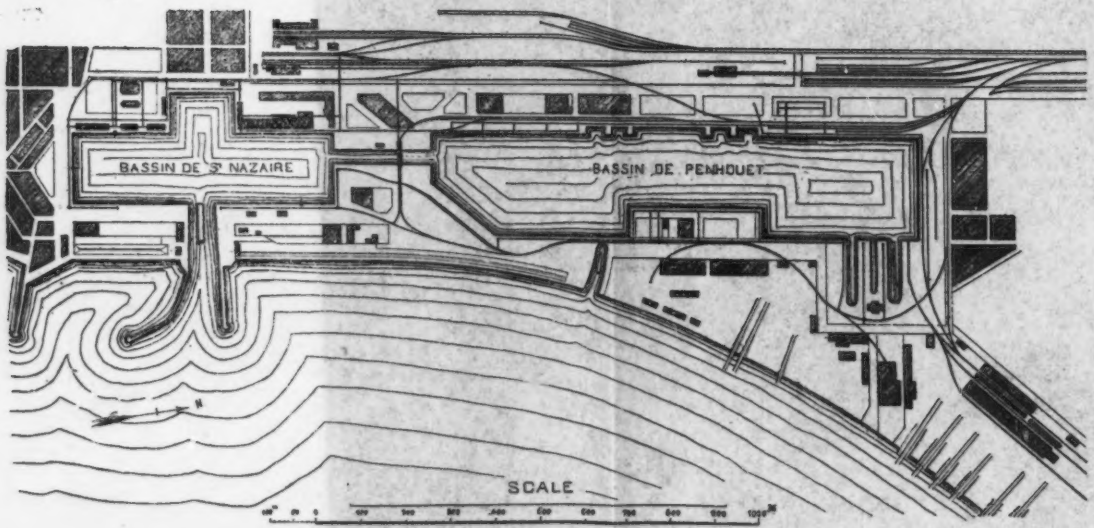
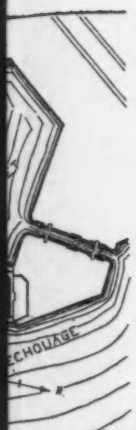


Fig 7. PORT DE St NAZAIRE.





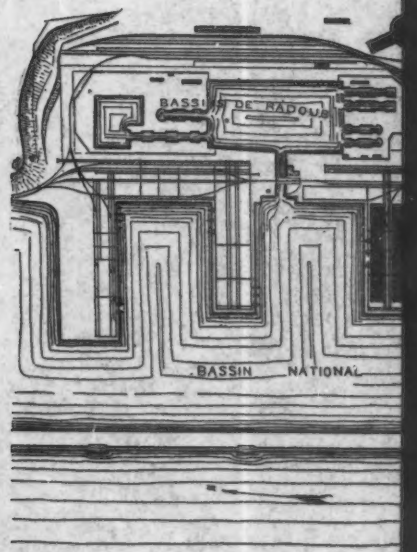


Fig 8. PORT DE BORDEAUX.

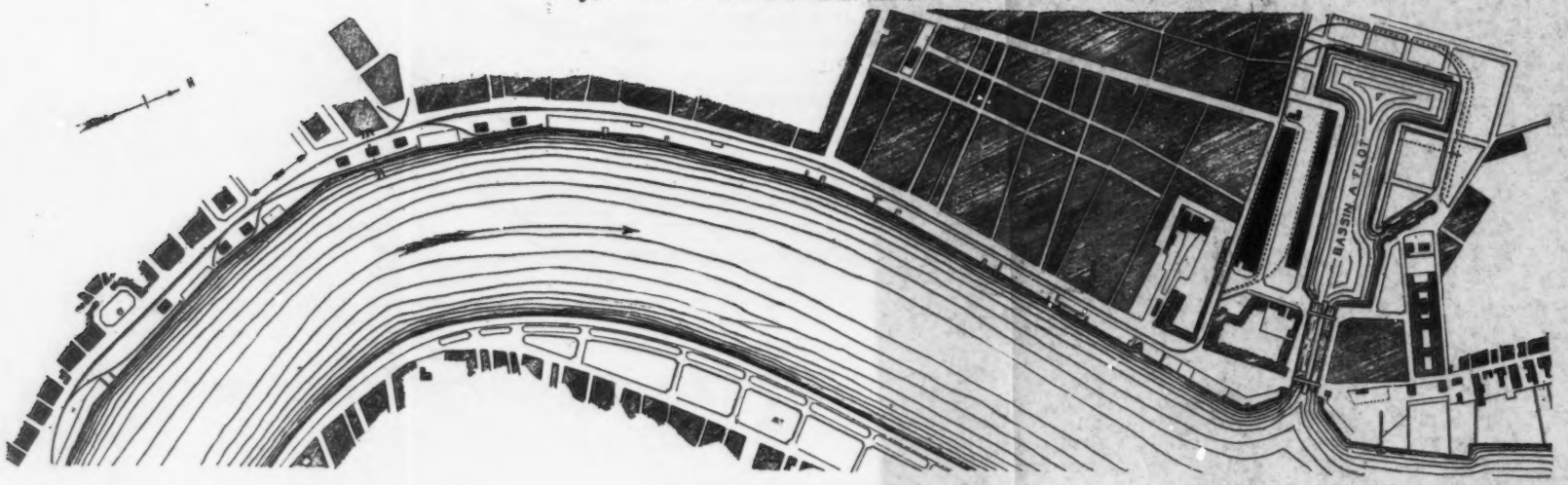
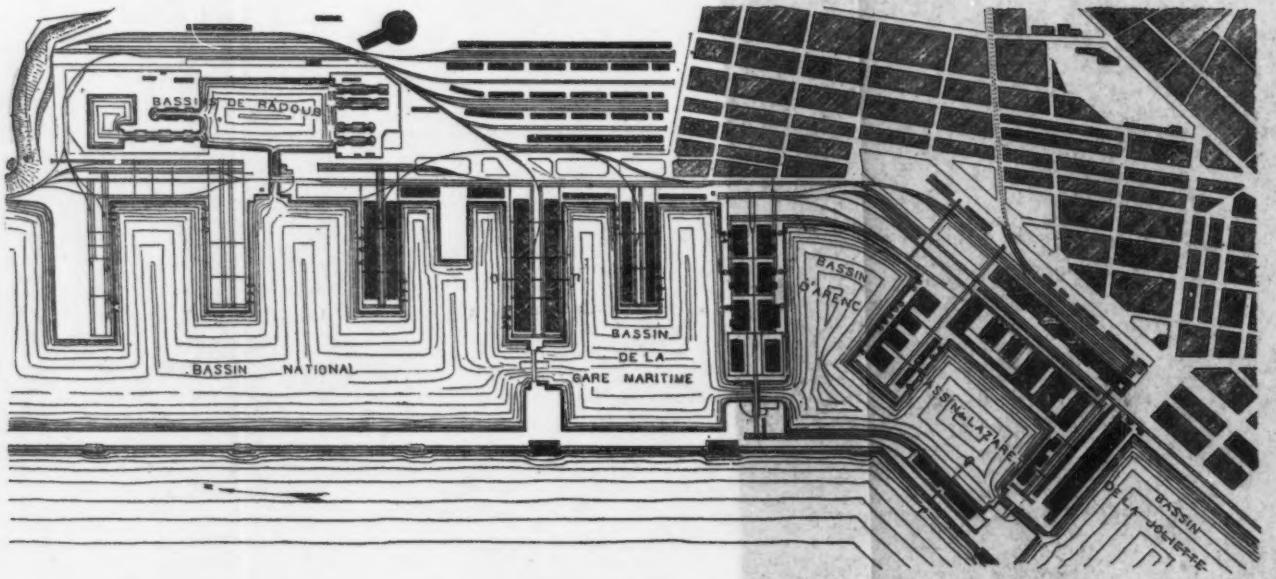
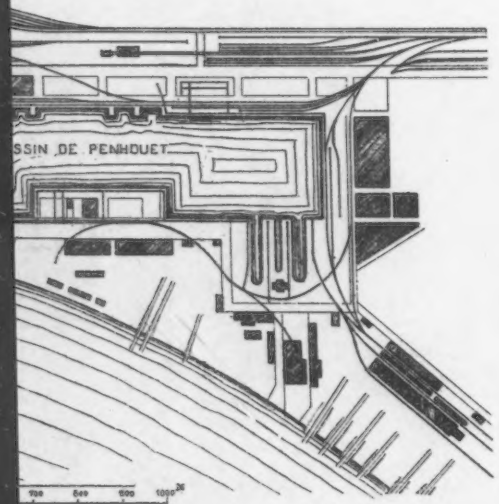
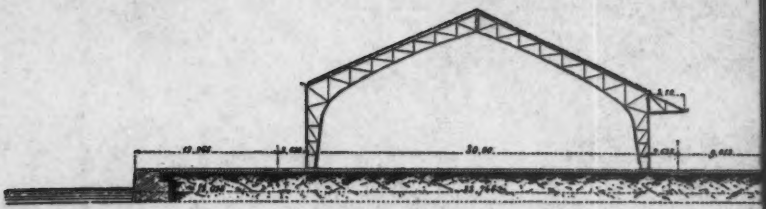


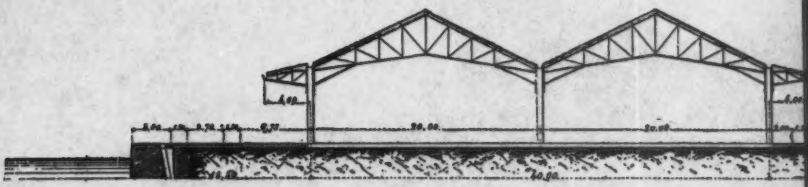
Fig 6.

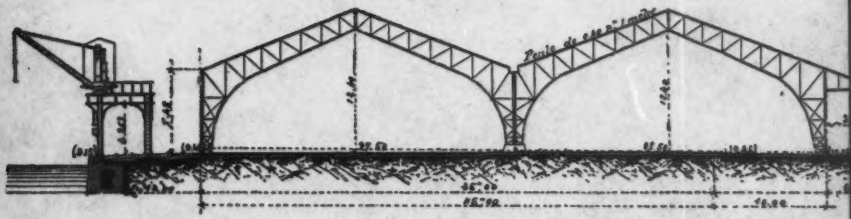
Fig 9. PORT DE MARSEILLE







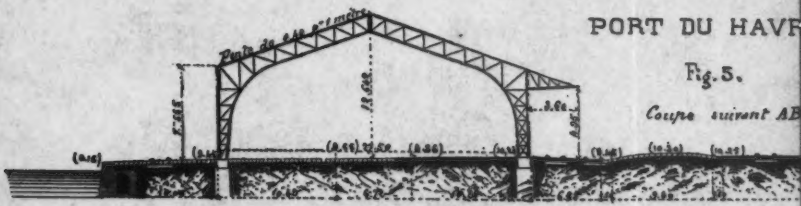




PORT DU HAVR

Fig. 5.

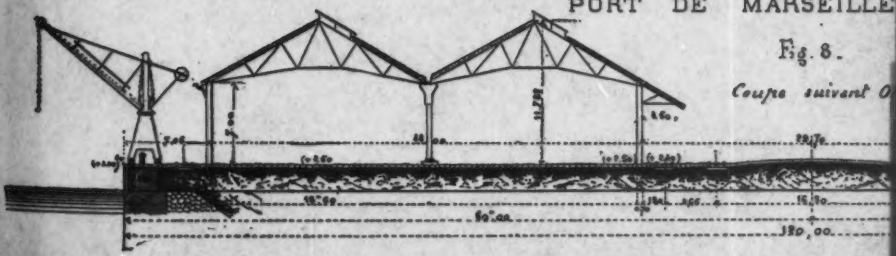
Coupe suivant AB



PORT DE MARSEILLE

Fig. 8.

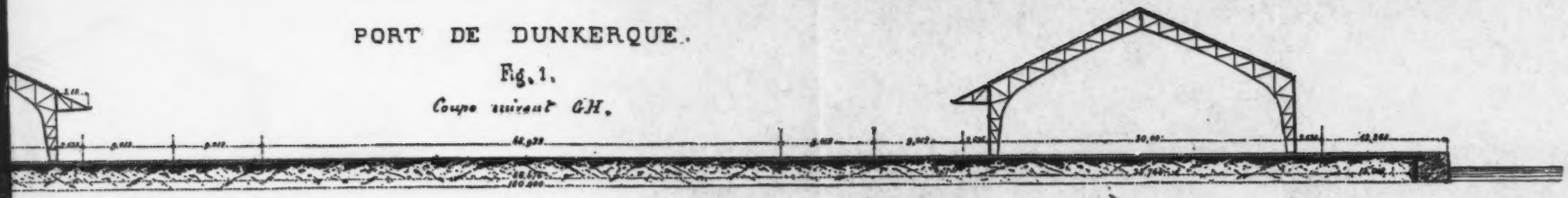
Coupe suivant C



PORT DE DUNKERQUE.

Fig. 1.

Coupe suivant GH.



PORT DE CALAIS

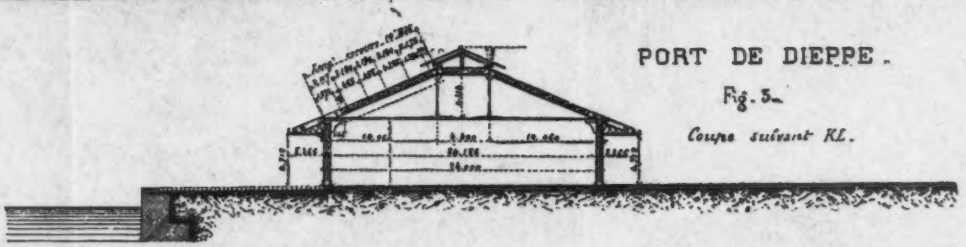
Fig. 2.

Coupe suivant IJ.

PORT DE DIEPPE.

Fig. 3.

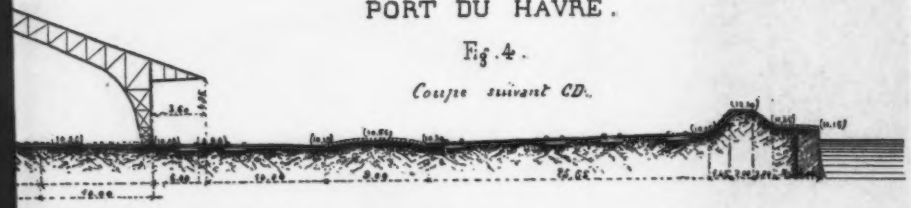
Coupe suivant KL.



PORT DU HAVRE.

Fig. 4.

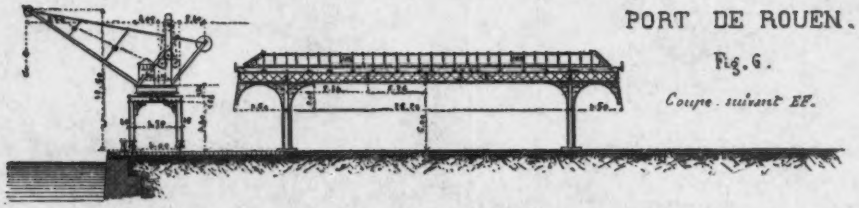
Coupe suivant CD.



PORT DE ROUEN.

Fig. 6.

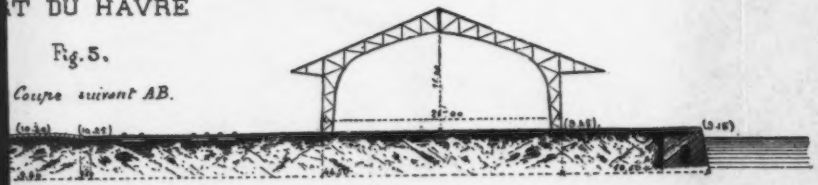
Coupe suivant EF.



T DU HAVRE

Fig. 5.

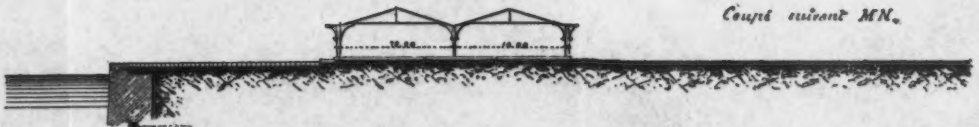
Coupe suivant AB.



PORT DE BORDEAUX.

Fig. 7.

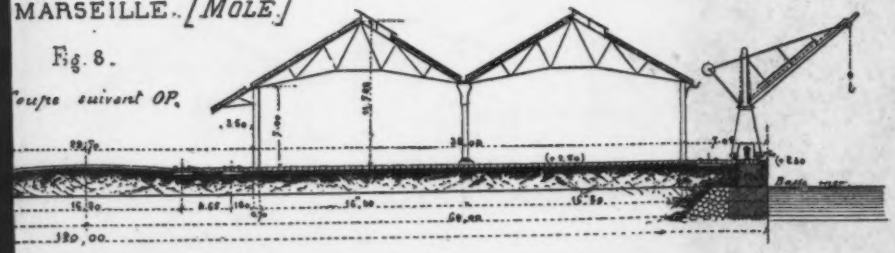
Coupe suivant MN.



MARSEILLE. [MÔLE.]

Fig. 8.

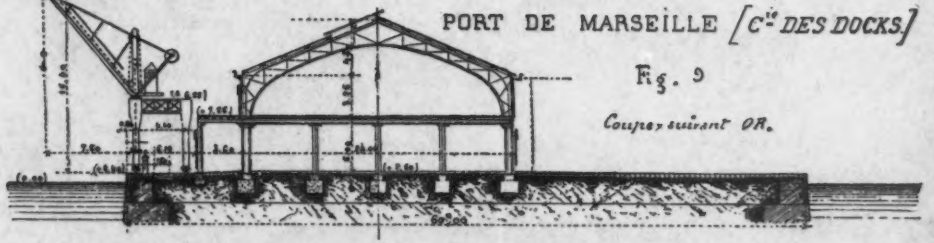
Coupe suivant OP.



PORT DE MARSEILLE [Cie DES DOCKS.]

Fig. 9

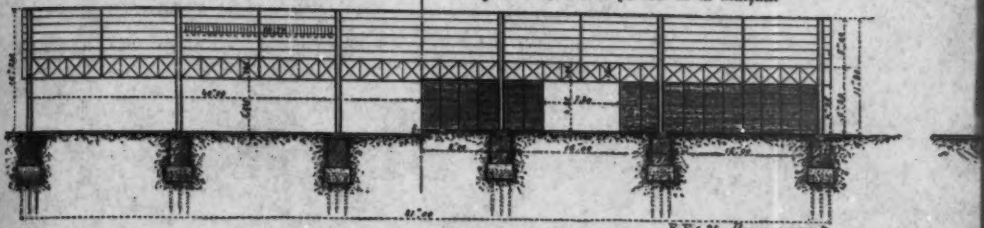
Coupe suivant QR.



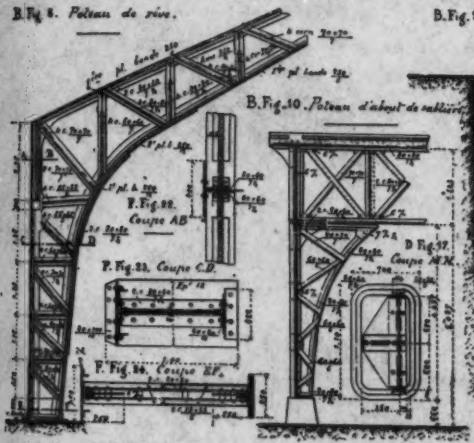
HANGARS DU HAVRE

A. Fig. 1. Demi-élévation du côté du quai.

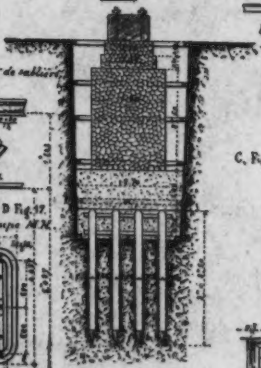
A. Fig. 2. Demi-élévation du côté de la marquise.



B. Fig. 8. Poteau de rive.



B. Fig. 9. Fondations.



B. Fig. 10. Poteau d'about de sabliere.

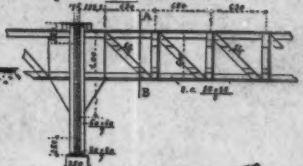
F. Fig. 22. Coupe AB.

F. Fig. 23. Coupe CD.

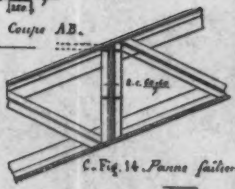
F. Fig. 24. Coupe EF.

D. Fig. 17. Coupe MN.

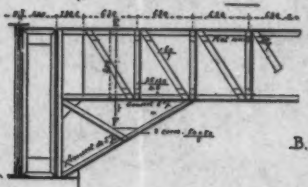
E. Fig. 26. Panne courante.



C. Fig. 13. Coupe AB.

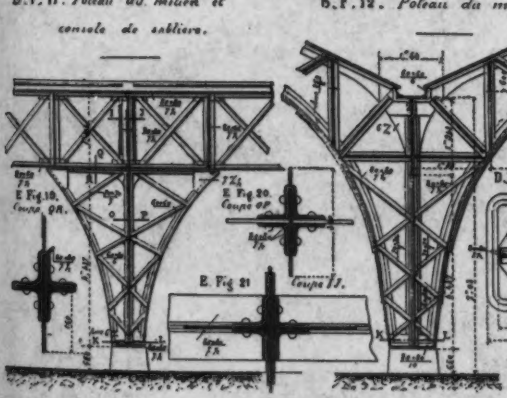


C. Fig. 14. Panne faîtiere



B. F. 11. Poteau du milieu et console de sabliere.

B. F. 12. Poteau du milieu.



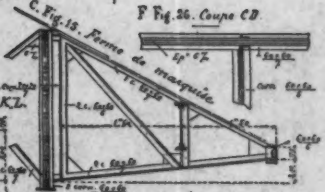
E. Fig. 18. Coupe QR.

E. Fig. 20. Coupe OP.

E. Fig. 21 Coupe TT.

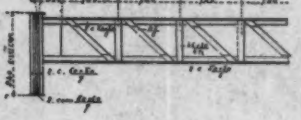
D. Fig. 18. Coupe KL.

C. Fig. 12. Ferme de marquise.



F. Fig. 26. Coupe CD.

C. Fig. 16. Panne courante de marquise.



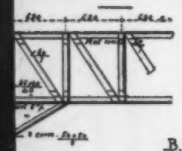
VOL. XXX, No. 644.
TRANS. AM. SOC. CIV. ENGRS.
DESPRES ON THE PLANT OF FRENCH PORTS.
PLATE III.

CONSTRUCTION DE HANGARS.

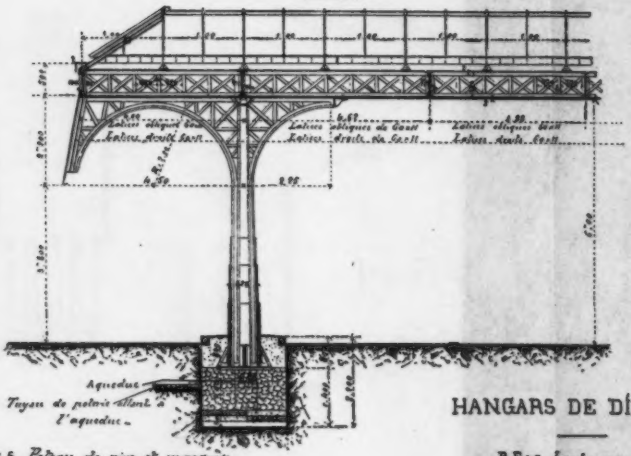
HANGARS DE ROUEN

A. Fig. 3 *Coupe longitudinale.*

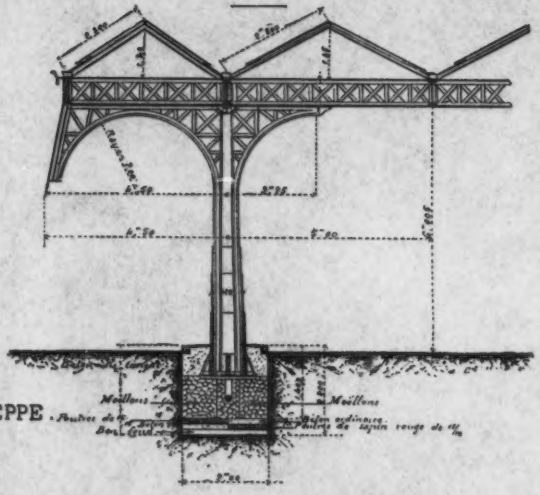
C. Fig. 14. *Panne faîtière*



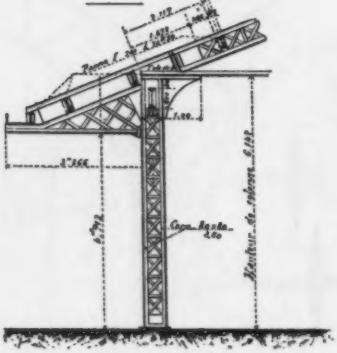
B. Fig. 4. *Demi-coupe transversale. (détails).*



B. Fig. 5. *Coupe longitudinale (détails)*

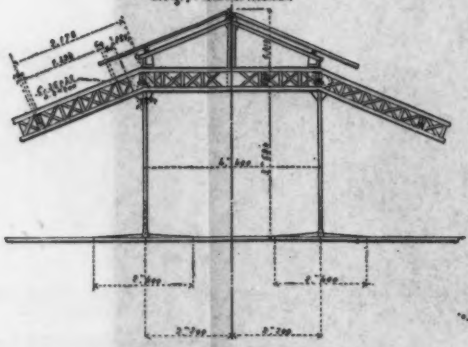


B. Fig. 6. *Poteaux de rive et marquise.*

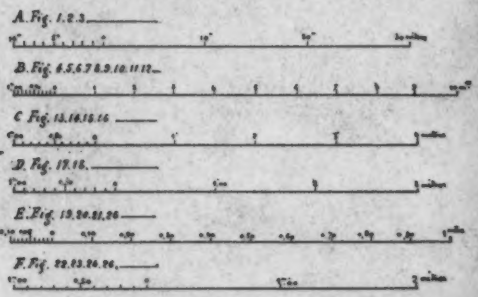


HANGARS DE DIEPPE.

B. Fig. 7. *Lanterneau.*



Echelles des différentes figures.

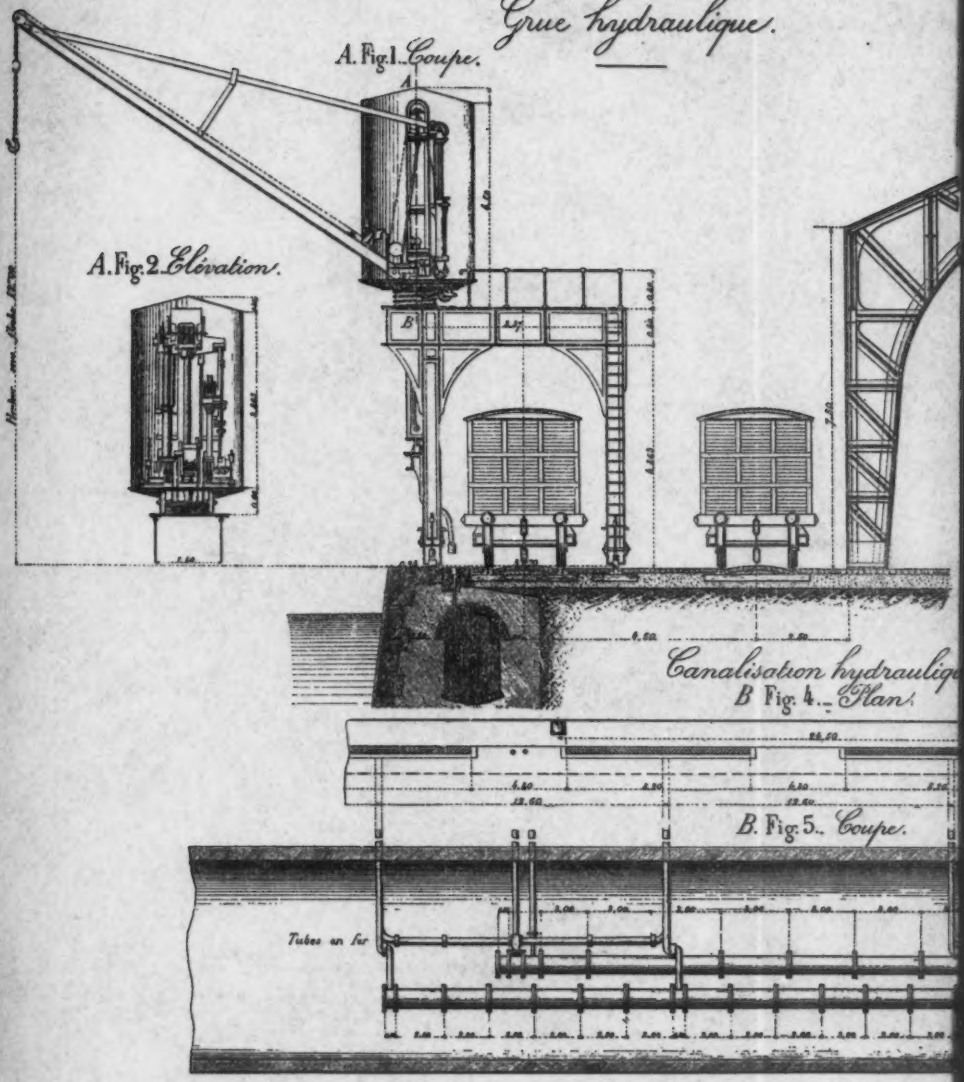


PORT DU HAVRE.

Grue hydraulique.

A. Fig. 1. Coupe.

A. Fig. 2. Elévation.



Canalisation hydraulique

B Fig. 4. Plan.

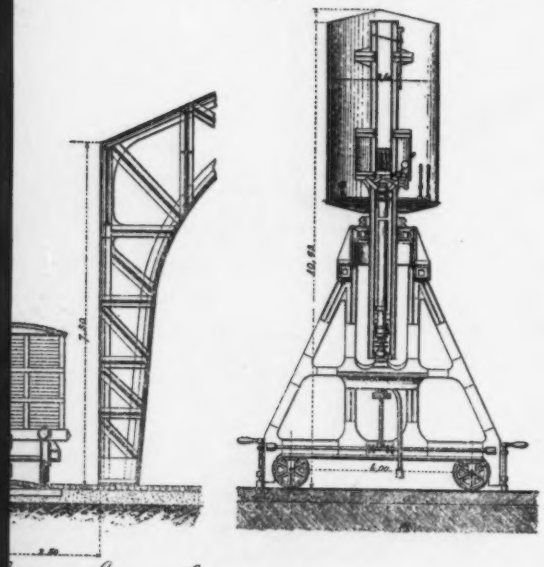
B. Fig. 5. Coupe.

Tubes en fer

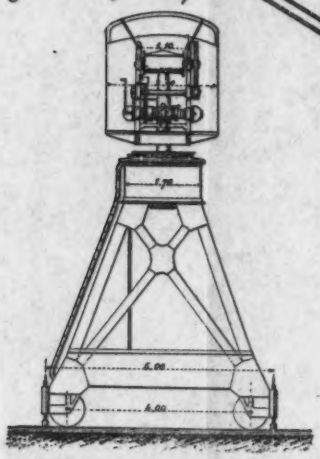
PORT DU HAVRE.

Grue à vapeur.

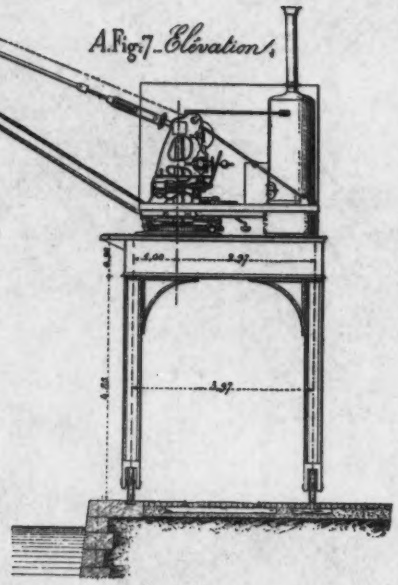
A. Fig. 3.. Coupe suivant AB



A. Fig. 6.. Coupe.



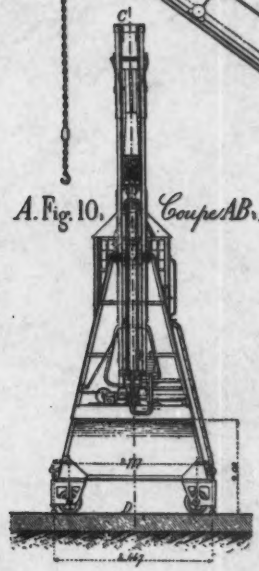
A. Fig. 7.. Elévation.



PORT DE MAR

Grue hydrau

A. Fig. 10.. Coupe AB.



ation hydraulique

Fig. 4.. Plan.

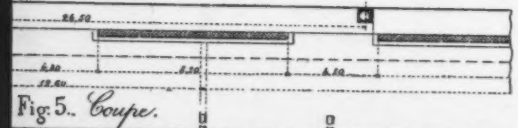
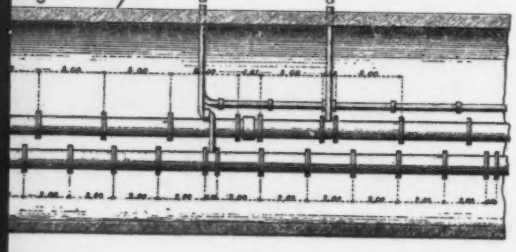
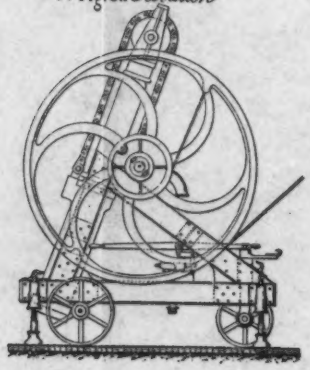


Fig. 5.. Coupe.

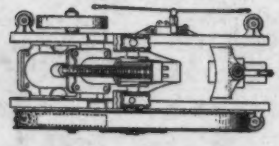


Treuil hydraulique.

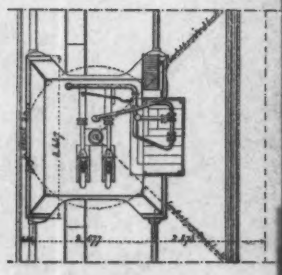
C. Fig. 8.. Elévation



C Fig. 9.. Plan.



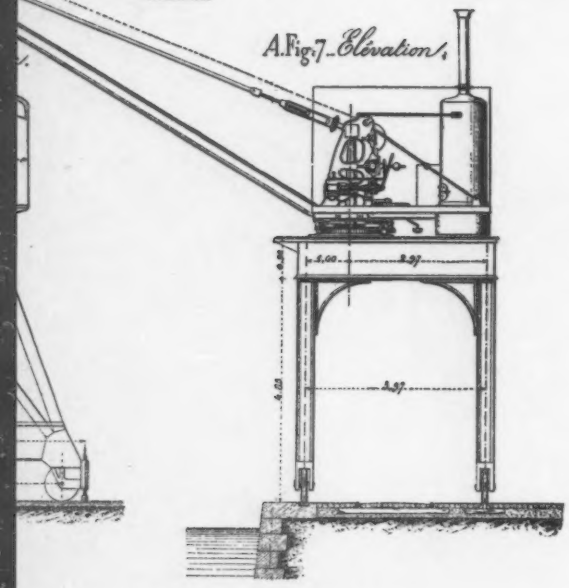
A. Fig. 12.. Coupe suivant EFG



PORT DU HAVRE.

Grue à vapeur.

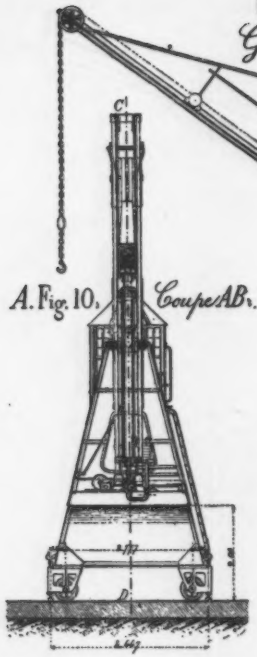
A. Fig. 7. *Élévation.*



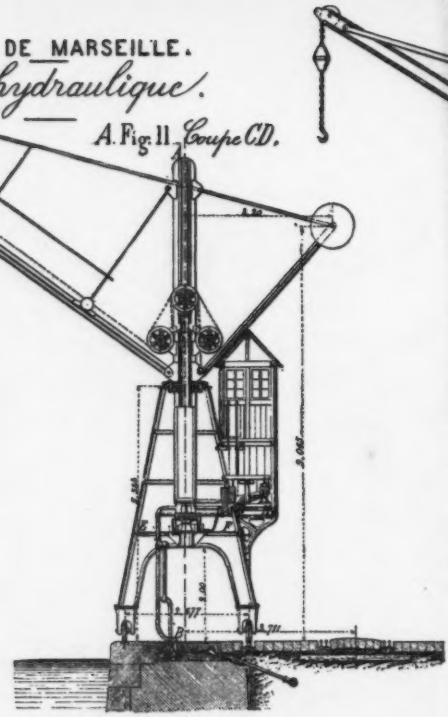
PORT DE MARSEILLE.

Grue hydraulique.

A. Fig. 10. *Coupe AB.*

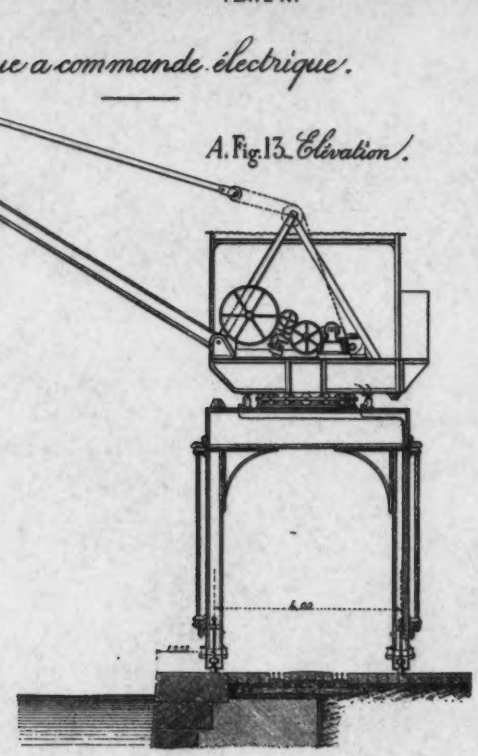


A. Fig. 11. *Coupe CD.*



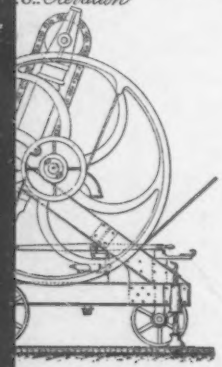
Grue à commande électrique.

A. Fig. 13. *Élévation.*

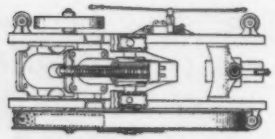


Treuil hydraulique.

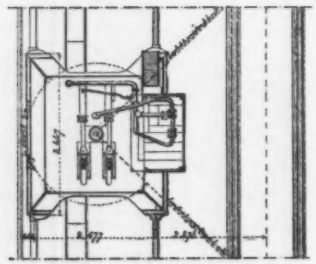
8. *Élévation*



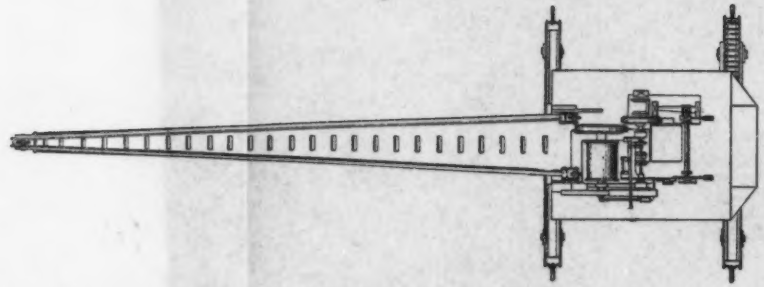
C Fig. 9. *Plan.*



A. Fig. 12. *Coupe suivant EFGH.*



A. Fig. 14. *Plan.*



A Scale A.

Scale B.

Scale C

in reducing as much as possible unnecessary cost and loss of time, promotes the greatest usefulness of these ports.

The works undertaken in France, from this point of view, during the last 10 years, and to which we have given a very rapid glance, have transformed the conditions of the work of commercial ports, at the same time that the large development of water-ways and railways has completed the system of communications with the interior of the country. The endeavor has also been during this period to give primary attention to the general necessities of commerce and to furnish quays which can respond to almost all needs. It remains, perhaps, now to determine whether it is not necessary to specialize certain parts of ports, and to give to them arrangements appropriate to particular needs; but everything cannot be undertaken at once, and the progress accomplished is a certain gauge by which the near future will be able to realize what remains to be done.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
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645.

(Vol. XXX.—November, 1893.)

THE DEVELOPMENT OF QUAY-CRANES IN THE PORT OF HAMBURG.

By CHR. NEHLS, Chief Engineer to River and Harbor Board of Hamburg, Germany.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

The City of Hamburg is situated 100 km. (62 miles) from the mouth of the River Elbe. Its harbor is accessible to ocean-going vessels, but from the harbor upwards only river vessels are employed. The mouth of the Elbe is subject to the tides. The flood tide in Hamburg rises to the height of nearly 2 m. (6½ ft.). Vessels with a draught of 7.2 m. (23 ft. 6 ins.) can go with the tide to Hamburg Harbor, under normal conditions, without discharging their cargo.

In the year 1891, the imports amounted to 8 900 000 tons, and the exports to 5 300 000 tons. A considerable amount of goods, 3 100 000 tons, was discharged from 3 758 ships at the quays, which extend over

NOTE.—Discussions on all papers presented to the International Engineering Congress will be published simultaneously in the number for December, 1893.

a length of 10.3 km. ($6\frac{1}{2}$ miles). On these quays the following cranes were working :

A.—Stationary Cranes.

1	steam crane, of.....	150 000 kg. lifting power.
1	" "	50 000 " "
1	" "	12 500 " "
1	hydraulic crane, of	5 000 " "
17	" cranes, each of..	2 000 " "
4	" " " ..	1 500 " "
4	" lifts, " ..	1 000 " "
10	gas cranes, " ..	400 " "
1	hand crane, " ..	40 000 " "
21	" cranes, " ..	2 500 " "
1	" crane, " ..	1 500 " "
4	" cranes, " ..	1 000 " "

B.—Traveling Cranes.

1	steam crane, of.....	7 500 kg. lifting power.
3	" cranes, each of.....	5 000 " "
1	" crane, of.....	3 000 " "
125	" cranes, each of.....	2 500 " "
123	" " "	1 500 " "
2	electric " "	2 500 " "
6	hand " "	2 500 " "
94	" " "	1 000 " "

Making a total of 421 cranes, with a collective lifting power of 1 000 000 kg., which is more or less uniformly distributed over the quays, and gives an average lifting power equal to 96 kg. per meter, or 30 kg. per foot, of quay length. Hamburg stands unrivaled in this respect.

A little more than a quarter of a century ago there were no quays and only a very few primitive cranes. Vessels to be loaded or discharged were moored to strong sets of piles driven into the bed of the river, called Duc d'Alben, and discharged and loaded from lighters by means of hand cranes. These lighters carried the cargo to the warehouses, which were built on the banks of canals and branches of the Elbe. These light-draught vessels could load and discharge alongside the warehouses.

But with the advance of railway enterprise and the great development of steam navigation a new carrying trade was called into existence which was unknown before. Part of the arriving goods were not taken to the storehouses, but were used as transit goods and carried by the railways directly to the steamers, and *vice versa*. Then, again, the size of the steamers was constantly increasing. The vessels took cargo for different receivers, and the goods had therefore to be sorted on arrival. The consequence of the great revival of commerce was that steamers had to make quicker voyages. Loading and discharging had therefore to be accelerated, and consequently efficient cranes had to be built. Under these circumstances the building of quays was begun for steamers in Hamburg, the first one being the Sandthor quai which was opened in the year 1866 (Plates 1 and 2).

It was a difficult task to construct the cranes so as to meet all requirements.

First of all, there was no doubt that traveling cranes only could be used, with the exception of cases where heavy loads had to be lifted. The necessity of discharging simultaneously from all the hatches, and the different position of these according to the length and construction of the steamers, was the reason why traveling cranes were deemed to be most practicable.

The variable beam of steamers, and the circumstance that at times lighters or river vessels have to be brought between the vessel and the quay, made it desirable to work the cranes with variable projecting jibs. The smallest projection was fixed at 6.8 m. (22½ ft.), the largest 9.1 m. (30 ft.), and the corresponding lifting power had to be 1 600 kg. in the former, and 1 200 kg. in the latter case. With the small jib goods can be lifted out of the hold of the ship and deposited in the sheds which run parallel to the quay, just behind the railway lines, the goods being carried clear of the railway lines lying between the crane rails and the shed. The greatest projection of jib is sufficient when a lighter of greatest beam is placed between the quay and steamer.

The highest point of the cranes could not be more than 6 m. (20 ft.) above the top of the rails, in order that the crane might swing round easily below the roofs of the sheds. The maximum lift was to be 10.3 m. (34 ft.), to allow the working of the cranes under all circumstances and at any height of the river. The velocity of lifting was fixed at 0.6

m. (2 ft.) per second. These were the conditions laid down for the design of the cranes. Several designs were sent in, the motive power being air, water and steam.

The offer of Brown Brothers, in Edinburgh, was recognized as the most suitable for the purpose, and this firm secured the order for 16 cranes. The motive power in their design was steam. The crane is placed upon a bogie, with a gauge of 2.36 m. (7 ft. 9 ins.), which carries in the middle the crane post.

By means of the piston in the cylinder C, the crane revolves upon the pin, and is guided by three wheels which run on a collar of the sole-plate (see Fig. 1, showing the steam cranes as constructed and improved in many respects in later years, as well as the unaltered principle of the construction).

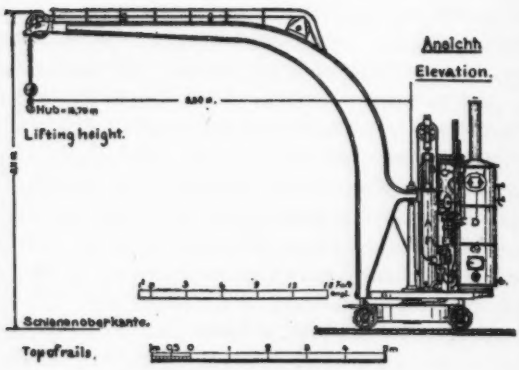
The crane is so balanced by the boiler that when working without load the two after guide wheels touch the guide ring; whereas, when loaded, the forward and larger wheel comes in contact with the guide ring.

To the movable platform are attached two vertical steam cylinders of 400 mm. (16 ins.) diameter and 1 830 mm. (6 ft.) stroke. The two piston-rods are connected by means of a cross-head which carries three movable pulleys of a set; whereas, the three fixed pulleys are placed between the cylinders. A chain is taken round these six pulleys, the end of which is carried over the top pulley of the jib. As soon as steam enters below the piston, the set of pulleys is forced outwards, and the load is lifted with a speed six times greater than that of the piston.

Between the two cylinders is fixed a hydraulic cylinder B, whose piston-rod is also connected with the cross-head so as to take part in the motion of the steam piston. This cylinder is used for the brake when the steam pistons ascend, thereby lifting the load; the water above the piston of the third cylinder is forced into a receiver. In this way the water passes an automatic valve, which is partially shut as soon as the flowing water exceeds a certain speed. For instance, in case the chain should break, the speed of the steam pistons is accelerated, and these draw with them the piston of the hydraulic cylinder. But the latter follows slowly, as the automatic valve is partially shut and the steam pistons are checked, and damage to the crane is prevented.

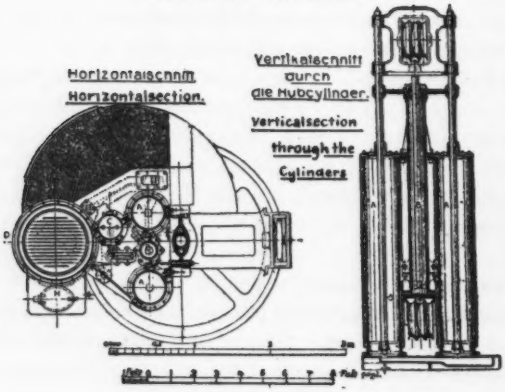
Having exhausted the steam, the pistons move downwards when the

FIG. 1.



Fahrbarer Dampfkrahn.

Moveable Steamcrane.



Fahrbarer Dampfkrahn.

A, steam cylinder. *B*, hydraulic cylinder. *C*, cylinder for swinging gear. *D*, boiler for 10 atmospheres with 2 500 kg., for 7.5 atmospheres with 1 500 kg. lifting power. *E*, starting lever. *F*, hand lever for the hydraulic valve. *G*, hand lever for the cylinder for swinging gear. *H*, water tank.

load is to be put down, and the water in the hydraulic cylinder below the piston is forced through another pipe into the receiver. In this way the water also passes through the valve, which is controlled by the crane man by means of a lever. According to the opening of the valve the loads can be put down quickly or slowly. The crane is worked by one man.

Steam is generated in the boiler D, having a combustion chamber with cross-tube of 340 mm. (13½ ins.) diameter. The exhaust steam is conducted to a heater, where the feed water is heated to about 25° Cent., and then forced into the boiler by means of a steam feed pump. The crane can be turned in the 0.55 part of a circle.

The forward part of the jib is made on the telescopic principle, and is worked by means of a chain which is taken round a shaft. In order to prevent any strain coming on the chain, holes are bored a foot apart, and a bolt is put in these which takes up the pressure from the chain. The maximum projection of the jib is 9.7 m. (31 ft. 6 ins.), but it has often happened that the jib extended 10 m. (33 ft.) when it was lowered, and it was possible to discharge from a lighter of 4 m. (14 ft.) beam between the ship and the quay into the hatch of the vessel.

The cranes are moved along the rails by manual labor, but, in order to bring them to their exact position, ratchet gear is fitted, a spur wheel turning the wheels of the bogie. Figure 1 shows this arrangement.

The following is the result of the trials which were instituted, to test the efficiency of the cranes.

The average number of kilograms of goods moved per hour was 26 150, of which one-half was lifted out of the hold on to the quay and the other half lifted from the quay and deposited in the lighters. The average lifting height was 5.15 m. (18 ft.). The average coal consumption was 9.75 kg. per 5 000 kg. of goods moved, but it must be borne in mind that the goods were slung and deposited without stoppages. The crane worked equally rapidly with large and small jib projection, and the weight of the load had no influence whatever upon the velocity of lifting. The crane worked almost noiselessly. The quantity of steam used was remarkably small, but this was due to the admission of a quantity of steam into the cylinder proportionate to the weight of the load and then cutting off the supply. From this it will be clear that the man working the crane must

be a skillful and experienced engineer. The steam pressure varied between 6 and 8 atm. (90 and 120 lbs.). When working in the ordinary way the coal consumption was larger, as there were many pauses when the cranes were not used, but steam had to be kept up.

Besides these steam cranes, hand cranes were erected which have a jib projection of 6 m. (20 ft.). They are for use in lowering and depositing goods out of the sheds into the lighters. In this case the lifting height is very small; they can easily be swung clear of the sheds, and the load let down into the lighters by its own weight. It would be too expensive to use steam cranes for this work.

Part of these hand cranes were of the ordinary design, and part of them were hydraulic cranes. In the latter case the crane post was hollow and used as a hydraulic cylinder. Its piston was connected with a set of pulleys, and the chain to these pulleys. The water was pumped into this cylinder out of an air-vessel. The water flowed into this air-vessel when the load descended, and compressed the air contained in the vessel. A set of pulleys lifted a balance weight when the load was lowered, and the weight of this balance weight, together with the pressure of the compressed air, caused the chain to ascend again automatically. These cranes, however, were very difficult to manage, and it was decided not to order any more.

Two movable steam cranes for heavy work were then erected, capable of lifting 3 000 and 5 000 kg., respectively. These are wheel-geared cranes. The engine turns a shaft, and this turns the other wheels by means of conical friction gear. The lifting, lowering and swinging of the cranes is done by the engine, which in this case is non-reversible, and therefore they work very rapidly. If the load of the heavier crane is greater than 2 500 kg., it has to be fitted with a balance weight which is always kept ready for use.

The following 27 cranes were the first erected:

1 steam-crane	of	5 000	kg.	lifting power.	
1 "	"	3 000	"	"	
17 steam-cranes	"	1 500	"	"	each.
4 hydraulic hand-cranes	of	1 000	kg.	lifting power	each.
4 ordinary "	"	1 000	"	"	"

When the quays were extended the number of cranes had to be increased. Table No. 1 shows this clearly. It should be mentioned that

TABLE No. 1.

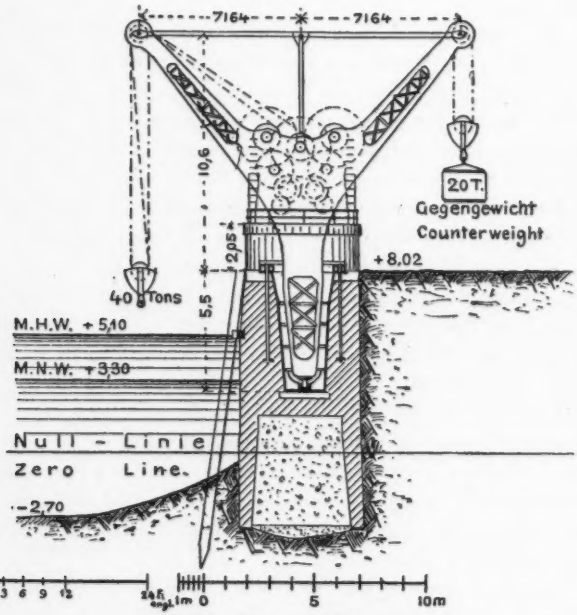
No.	When built.	Position.	Number of cranes. Fixed.	Number of cranes. Movable.	Lifting power. Kg.	Projection. Center of pin to chain. Feet.	Projection. Center of pin to chain. M.	Projection. Edge of quay to chain. Feet.	Projection. Edge of quay to chain. M.	Lifting height. Feet.	Lifting height. M.	Motor.	Principle of construction.	Arrangement of brake.	Remarks.
1..	1866....	Sandthor quay	.....	17	1 500	22′ 3″	6.80	17′ 0″	5.17						
2..		"	.....	8	1 000	19′ 8″	6.00	14′ 4″	4.37						
3..		"	.....	1	3 000	22′ 6″	6.86	17′ 2″	5.23	....	.....	Hydraulic power			
4..	1867....	"	.....	1	5 000	23′ 7″	7.20	18′ 3″	5.57	.....	.....	"	.....	.....	Lifts.
5..	1872..	Kaiser quay	.....	24	1 500	29′ 10″ or	9.1 or	24′ 3″ or	7.4 or	.....	.....	Hand			
		Dalmann quay	.....	5	2 500	25′ 11″	7.9	20′ 4″	6.2	.....	.....	Gas			
6..		Kaiser quay	1	.....	12 500	23′ 6″	7.16	15′ 5″	4.70	.....	....	Hand			
7..		Dalmann quay	1	.....	40 000	23′ 6″	7.16	15′ 2″	4.61	.....	.....	Hydraulic power	.....	.....	Near the water.
8..		Kaiser & Dalmann quay	.....	10	1 000	19′ 8″	6.00	14′ 1″	4.29	.....	.....	"	.....	.....	In the shed on the rails
9..	1875....	Lengthened Sandthor quay	.....	4	1 500	25′ 5″	7.74	20′ 0″	6.11	.....	.....	"	.....	.....	In the street.
10..		" "	.....	1	2 500	25′ 5″	7.74	20′ 0″	6.11	.....	....	"	.....	.....	Near the sand pier.
11..		" "	.....	1	5 000	26′ 11″	8.20	21′ 7″	6.57	.....	.....	Hand			
12..		" "	.....	2	1 000	19′ 8″	6.00	14′ 4″	4 37						
13..	1876....	Dalmann quay	.....	12	1 500	32′ 2″	9.80	26′ 7″	8.10						
14..		"	.....	11	1 000	21′ 6″	6.55	15′ 11″	4.85						
15..	1877....	Hübener quay	.....	6	1 500	32′ 2″	9.80	26′ 7″	8.10						
16..		For distribution	.....	3	1 500	25′ 5″	7.75	19′ 10″	6.05						
17..		Hübener quay	.....	4	1 000	21′ 6″	6.55	15′ 11″	4.85						
18..	1878...	For distribution	.....	5	1 500	25′ 5″	7.75	19′ 10″	6.05						
19..		"	.....	1	2 500	25′ 5″	7.75	19′ 10″	6.05						
20..		"	.....	1	1 500	25′ 5″	7.75	19′ 10″	6.05						
21..		Strand quay	.....	5	1 000	21′ 6″	6.55	15′ 11″	4.85						
22..	1880....	"	.....	1	2 500	26′ 3″	8.00	20′ 8″	6.30						
23..		"	.....	10	1 500	25′ 5″ to 32′ 2″	7.75 to 9.80	19′ 10″ to 26′ 7″	6.05 to 8.10						
24..	1882....	Kaiser quay	.....	1	7 500	27′ 0″	8.23	21′ 5″	6.52						
25..	1884....	For distribution	.....	8	1 500	25′ 5″	7.75	19′ 10″	6.05						
26..		"	.....	7	2 500	26′ 3″	8.00	20′ 8″	6.30						
27..	1885 ...	"	.....	2	1 500	32′ 2″	9.80	26′ 7″	8.10						
28..		"	.....	2	2 500	25′ 5″	7.75	19′ 10″	6.05						
29..	.....	Sandthor quay	3	.....	2 500	7′ 7″	2.32	4′ 7″	1.40*						
		For distribution	7	.....	2 500	9′ 0″	2.74	5′ 3″	1.60*						
30..	1886-88.	For distribution	.....	2	2 500	32′ 2″	9.80	26′ 7″	8.10	45′ 1″	13.75	Steam	Blocks	Hydraulic brake	Substitute for older cranes.
31..		"	.....	7	1 500	25′ 5″	7.75	19′ 10″	6.05	36′ 1″	11.00	"	"	"	
32..	1889....	Versmann quay	.....	25	1 500	32′ 2″	9.80	26′ 6″	8.07	45′ 1″	13.75	" 112½ lbs. / 7½ atm.	"	"	
33..		Amerika quay	.....	12	2 500	32′ 2″	9.80	26′ 6″	8.07	45′ 1″	13.75	" 150 lbs. / 10 atm.	"	"	
34..		Krahnhöft	1	.....	150 000	56′ 9″	17.30	32′ 10″	10.00	.....	.....	" 75 lbs. / 5 atm.			
35..		Versmann quay	.....	15	1 000	29′ 6″	9.00	23′ 10″	7.27	33′ 7″	10.25	Hand	Wheel gearing.	Centrifugal brake.	
36..		Amerika quay	.....	8	1 000	29′ 6″	9 00	23′ 10″	7.27	33′ 7″	10.25	"	"	"	
37..		Versmann and Amerika quay	.....	6	2 500	10′ 8″	3.25	5′ 10″	1.79*	25′ 0″	7.00	"	"	" ...	Wall cranes.
38..	1889-90.	Petersen quay	.....	32	2 500	36′ 1″	11.00	27′ 1″	8.25	45′ 1″	13.75	Steam, 195 lbs. / 13 atm.	Blocks.	Hydraulic brake...	Semi-arched.
39..		Asia quay	.....	27	2 500	36′ 1″	11.00	27′ 1″	8.25	59′ 0″	18.00	" "	"	" ...	"
40..	1889-90.	Krahnhöft	.....	4	1 500	27′ 11″	8.50	22′ 3″	6.77	45′ 1″	13.75	Steam	"	" ...	
41..		Amerika quay	.....	4	1 500	32′ 2″	9.80	26′ 6″	8.07	45′ 1″	13.75	"	"	" ...	
42..		For distribution	.....	2	2 500	25′ 5″	7.75	19′ 9″	6.02	36′ 1″	11.00	"	"	" ...	Partly substitutes.
43..		"	.....	5	2 500	26′ 3″	8.00	20′ 7″	6.27	45′ 1″	13.75	"	"	" ...	
44..		"	.....	4	2 500	32′ 2″	9.80	26′ 6″	8.07	45′ 1″	13.75	"	"	" ...	
45..		Petersen quay	.....	12	1 000	33′ 9″	10.30	23′ 11″	7.30	45′ 1″	13.75	Hand	Wheel gearing.	Centrifugal brake..	Semi-arched.
46..		Asia quay	.....	9	1 000	33′ 9″	10.30	23′ 11″	7.30	45′ 1″	13.75	"	"	"	"
47..		Peterson quay	.....	12	1 000	11′ 6″	3.50	19′ 4″	5.90*	16′ 5″	5.00	"	"	" ..	Semi-arched at the back of the sheds.
48..		Asia quay	10	.....	2 500	14′ 1″	4.30	9′ 1″	2.77*	.....	.....	"	Winch	.....	Wall cranes.
49..		Amerika quay	.....	4	1 000	29′ 6″	9.00	23′ 10″	7.27	33′ 7″	10.25	"	Wheel gearing.	Centrifugal brake..	Substitutes.
50..	1891....	Kirchenpauer quay	.....	9	2 500	32′ 2″	9.80	26′ 4″	8.03	45′ 1″	13.75	Steam	Blocks	Hydraulic brake.	
51..		"	.....	4	1 000	11′ 6″	3 50	19′ 4″	5.90*	16′ 5″	5.00	Hand	Wheel gearing.	Centrifugal brake..	Semi-arched at the back of the sheds.
52..		Petersen quay	.....	2	2 500	36′ 1″	11.00	27′ 1″	8.25	45′ 1″	13.75	Electricity	.....	.....	Semi-arched.
53..		For distribution	.....	13	2 500	25′ 9″ to 32′ 2″	7′ 25″ to 9 80	18′ 1″ to 26′ 4″	5.52 to 8.03	36′ 1″ to 45′ 1″	11.0 to 13.75	Steam, 150 lbs. / 10 atm.	Blocks	Hydraulic brake...	Partly substitutes.
54..		Asia quay	.....	2	2 500	36′ 1″	11.00	27′ 1″	8.25	59′ 0″	18.00	" 150 lbs. / 10 atm.	"	" ...	Semi-arched.
55..		Amerika quay	.....	1	5 000	31′ 2″	9.50	25′ 6″	7.77	.....	.....	Steam	.....	Band brake and centrifugal brake.	
56..		Baakenhöft	1	.....	50 000	41′ 10″	12.75	29′ 2″	8.90	59′ 0″	18.00	"	.....	Weston's brake.	
		Besides these, there are the following lifting arrangements.	24	374	.....	.....	.....	.....	.....	33′ 10″	10.30	" 90-120 lbs. / 6-8 atm.	Blocks	Hydraulic brake...	
												Hand	Wheel gearing.	Band brake	Four of these cranes worked with the help of hydraulic power.
		Quaispeicher "A"	4	.....	1 500	.....	.....	.....	.....	.....	.....	Steam	"		
		" "	4	.....	1 000	.....	.....	.....	.....	.....	.....	"	"		
		" "	4	.....	1 000	.....	.....	.....	.....	.....	.....	"	Blocks	Hydraulic brake.	
		" "B"	10	.....	400	.....	.....	.....	.....	.....	.....	"	"	"	
		" "	1	.....	2 500	.....	.....	.....	.....	.....	.....	"	Wheel gearing.		
		Magdeburger quay	9	.....	2 000	16′ 5″	5.00	12′ 6″	3.80	.....	.....	Hand	"		
		" "	6	.....	2 000	11′ 6″	3.50	6′ 5″	1.95*	.....	.....	"	"	Band brake.	
		" "	2	.....	2 000	9′ 10″	3.00	4′ 11″	1.50*	35′ 9″	10.90	Steam, 110 lbs. / 7½ atm.	Blocks	Hydraulic brake...	
		Brooksfleth	1	.....	5 000	18′ 0″	5.50	13′ 2″	4.00	35′ 9″	10.90	" 130 lbs. / 8⅝ atm.	"	"	
		Wilhelminen platz	1	.....	1 500	.....	.....	.....	.....	.....	.....	" 67½ lbs. / 4½ atm.	Wheel gearing.		
		Total	66	374						34′ 1″	10.40	Hand	"		

10..		" "	.....	1	5 000	26' 11"	8.20	21' 7"	6.57	.....	.....	Hand				
11..		" "	.....	1	5 000	26' 11"	8.20	21' 7"	6.57	.....	.....	Hand				
12..		" "	.....	2	1 000	19' 8"	6.00	14' 4"	4.37							
13..	1876....	Dalmann quay.....	.....	12	1 500	32' 2"	9.80	26' 7"	8.10							
14..		"	.....	11	1 500	21' 6"	6.55	15' 11"	4.85							
15..	1877....	Hübener quay	.....	6	1 500	32' 2"	9.80	26' 7"	8.10							
16..		For distribution.....	.....	3	1 500	25' 5"	7.75	19' 10"	6.05							
17..		Hübener quay.....	.....	4	1 000	21' 6"	6.55	15' 11"	4.85							
18..	1878...	For distribution.....	.....	5	1 500	25' 5"	7.75	19' 10"	6.05							
19..		"	.....	1	2 500	25' 5"	7.75	19' 10"	6.05							
20..		"	.....	1	1 500	25' 5"	7.75	19' 10"	6.05							
21..		Strand quay	.....	5	1 000	21' 6"	6.55	15' 11"	4.85							
22..	1880....	"	.....	1	2 500	26' 3"	8.00	20' 8"	6.30							
23..		"	.....	10	1 500	25' 5" to 32' 2"	7.75 to 9.80	19' 10" to 26' 7"	6.05 to 8.10							
24..	1882....	Kaiser quay	.....	1	7 500	27' 0"	8.23	21' 5"	6.52							
25..	1884....	For distribution	.....	8	1 500	25' 5"	7.75	19' 10"	6.05							
26..		"	.....	7	2 500	26' 3"	8.00	20' 8"	6.30							
27..	1885....	"	.....	2	1 500	32' 2"	9.80	26' 7"	8.10							
28..		"	.....	2	2 500	25' 5"	7.75	19' 10"	6.05							
29..	.....	Sandthor quay	3	.....	2 500	7' 7"	2.32	4' 7"	1.40*							
	.....	For distribution	7	.....	2 500	9' 0"	2.74	5' 3"	1.60*							
30..	1886–88.	For distribution.....	.....	2	2 500	32' 2"	9.80	26' 7"	8.10	45' 1"	13.75	Steam	Blocks.....	Hydraulic brake...	Substitute for older cranes.	
31..		"	.....	7	1 500	25' 5"	7.75	19' 10"	6.05	36' 1"	11.00	"	"	"		
32..	1889....	Versmann quay	.....	25	1 500	32' 2"	9.80	26' 6"	8.07	45' 1"	13.75	" {112½ lbs. / 7½ atm.}	"	"		
33..		Amerika quay.....	.....	12	2 500	32' 2"	9.80	26' 6"	8.07	45' 1"	13.75	" {150 lbs. / 10 atm.}	"	"		
34..		Krahnhöft.....	1	.....	150 000	56' 9"	17.30	32' 10"	10.00	.....	.....	" {75 lbs. / 5 atm.}				
35..		Versmann quay	.....	15	1 000	29' 6"	9.00	23' 10"	7.27	33' 7"	10.25	Hand	Wheel gearing.	Centrifugal brake.		
36..		Amerika quay	.....	8	1 000	29' 6"	9 00	23' 10"	7.27	33' 7"	10.25	"	"	"		
37..		Versmann and Amerika quay.	.....	6	2 500	10' 8"	3.25	5' 10"	1.79*	25' 0"	7.00	"	"	" ...	Wall cranes.	
38..	1889–90.	Petersen quay.....	.....	32	2 500	36' 1"	11.00	27' 1"	8.25	45' 1"	13.75	Steam, {195 lbs. / 13 atm.}	Blocks.	Hydraulic brake...	Semi-arched.	
39..		Asia quay.....	.....	27	2 500	36' 1"	11.00	27' 1"	8.25	59' 0"	18.00	" "	"	" ...	"	
40..	1889–90.	Krahnhöft.....	.....	4	1 500	27' 11"	8.50	22' 3"	6.77	45' 1"	13.75	Steam.....	"	" ...		
41..		Amerika quay.....	.....	4	1 500	32' 2"	9.80	26' 6"	8.07	45' 1"	13.75	"	"	" ...		
42..		For distribution.....	.....	2	2 500	25' 5"	7.75	19' 9"	6.02	36' 1"	11.00	"	"	" ...	Partly substitutes.	
43..		"	.....	5	2 500	26' 3"	8.00	20' 7"	6.27	45' 1"	13.75	"	"	" ...		
44..		"	.....	4	2 500	32' 2"	9.80	26' 6"	8.07	45' 1"	13.75	"	"	" ...		
45..		Petersen quay.....	.....	12	1 000	33' 9"	10.30	23' 11"	7.30	45' 1"	13.75	Hand.....	Wheel gearing.	Centrifugal brake..	Semi-arched.	
46..		Asia quay	.....	9	1 000	33' 9"	10.30	23' 11"	7.30	45' 1"	13.75	"	"	" ..	"	
47..		Peterson quay.....	.....	12	1 000	11' 6"	3.50	19' 4"	5.90*	16' 5"	5.00	"	"	" ..	Semi-arched at the back of the sheds.	
48..		Asia quay.....	10	.....	2 500	14' 1"	4.30	9' 1"	2.77*	.....	.....	"	Winch	.....	Wall cranes.	
49..		Amerika quay.....	.....	4	1 000	29' 6"	9.00	23' 10"	7.27	33' 7"	10.25	"	Wheel gearing.	Centrifugal brake..	Substitutes.	
50..	1891....	Kirchenpauer quay.....	.....	9	2 500	32' 2"	9.80	26' 4"	8.03	45' 1"	13.75	Steam.....	Blocks.....	Hydraulic brake.		
51..		"	.....	4	1 000	11' 6"	3.50	19' 4"	5.90*	16' 5"	5.00	Hand.	Wheel gearing.	Centrifugal brake..	Semi-arched at the back of the sheds.	
52..		Petersen quay.....	.....	2	2 500	36' 1"	11.00	27' 1"	8.25	45' 1"	13.75	Electricity	.....	.....	Semi-arched.	
53..		For distribution.....	.....	13	2 500	25' 9" to 32' 2"	7' 25" to 9 80	18' 1" to 26' 4"	5.52 to 8.03	36' 1" to 45' 1"	11.0 to 13.75	Steam, {150 lbs. / 10 atm.}	Blocks	Hydraulic brake...	Partly substitutes.	
54..		Asia quay.....	.....	2	2 500	36' 1"	11.00	27' 1"	8.25	59' 0"	18.00	" {150 lbs. / 10 atm.}	"	" ...	Semi-arched.	
55..		Amerika quay.....	.....	1	5 000	31' 2"	9.50	25' 6"	7.77	.....	.....	Steam	.....	Band brake and centrifugal brake.		
56..		Baakenhöft	1	.....	50 000	41' 10"	12.75	29' 2"	8.90	59' 0"	18.00	"	.....	Weston's brake.		
		Besides these, there are the following lifting arrangements.	24	374	.....	.....	.....	.....	.....	33' 10"	10.30	" {90–120 lbs. / 6–8 atm.}	Blocks.....	Hydraulic brake...		
												Hand.....	Wheel gearing.	Band brake.....	Four of these cranes worked with the help of hydraulic power.	
		Quaispeicher "A".....	4	.....	1 500	.....	.....	.....	.....	.....	.....	Steam.....	"			
		" "	4	.....	1 000	.....	.....	.....	.....	.....	.....	"	"			
		" "	4	.....	1 000	.....	.....	.....	.....	.....	.....	"	Blocks	Hydraulic brake.		
		" "B".....	10	.....	400	.....	.....	.....	.....	.....	.....	"	"	"		
		" "	1	.....	2 500	.....	.....	.....	.....	.....	.....	"	Wheel gearing.			
		Magdeburger quay.....	9	.....	2 000	16' 5"	5.00	12' 6"	3.80	.....	.....	Hand.....	"			
		" "	6	.....	2 000	11' 6"	3.50	6' 5"	1.95*	.....	.....	"	"	Band brake.		
		" "	2	.....	2 000	9' 10"	3.00	4' 11"	1.50*	35' 9"	10.90	Steam, {110 lbs. / 7½ atm.}	Blocks	Hydraulic brake...		
		Brooksfleth	1	.....	5 000	18' 0"	5.50	13' 2"	4.00	35' 9"	10.90	" {130 lbs. / 8⅝ atm.}	"	"		
		Wilhelminen platz.....	1	.....	1 500	.....	.....	.....	.....	.....	.....	" {67½ lbs. / 4½ atm.}	Wheel gearing.			
										34' 1"	10.40	Hand.....	"			
		Total	66	374						45' 1"	13.75	Steam.....	Blocks	Hydraulic brake.		
										33' 7"	10.25	Hand.....	Wheel gearing.	Band brake.		
										45' 1"	13.75	Steam.....	Blocks	Hydraulic brake.		
										35' 9"	10.90	"	"	" ...	Substitute for older cranes.	
										33' 7"	10.25	Hand.....	Wheel gearing.	Band brake.		
										35' 9"	10.90	Steam.....	Blocks	Hydraulic brake...		
										45' 1"	13.75	" {150 lbs. / 10 atm.}	"	"		
										35' 9"	10.90	Steam.....	"	Friction brake.		
										33' 7"	10.25	Hand.....	Wheel gearing.	Band brake.		
										45' 1"	13.75	Steam, {150 lbs. / 10 atm.}	Blocks	Hydraulic brake...	Partial substitute for older cranes.	
										36' 1" to 45' 1"	11.0 to 13.75	" {112½ lbs. / 7½ atm.}	"	"		
												"	Wheel gearing.	Band brake.		
										36' 1"	11.00	" {112½ lbs. / 7½ atm.}	Blocks	Hydraulic brake.		
										45' 1"	13.75	" {150 lbs. / 10 atm.}	"	"		
										45' 1"	13.75	"	"	"		
										36' 1"	11.00	"	"	"		
												Hand.....	Wheel gearing.	Band brake.	Wall cranes at the back of the sheds.	

* Edge of platform to chain.

with the cranes of No. 5, and also those erected at a later period, the variable projecting jib was done away with, as it did not prove successful. Some of the cranes were fitted with curved jibs, in order to clear the high bulwarks of large steamers and also the railway tracks. These curved jibs are more flexible than the straight ones, and better fitted to stand the shocks to which the load on the chain is exposed. This system of jib, which proved a success, has since been adopted in all steam-cranes.

FIG. 2



Handkrahn am Dalmannquai.

Handcrane on the Dalmannquai.

The crane under No. 7 can lift 40 000 and 20 000 kg. respectively. In the former case the stronger arm is used, and in the latter the smaller one. These arms are on opposite sides of the crane (see Fig. 2).

This crane is worked by 12 men and has four handles. With the smaller arm 10 000 kg. can be lifted directly, and 20 000 kg. by means

of a movable pulley; whereas, with the stronger arm, loads of 27 500 kg. can be lifted by means of a double block and of 40 000 kg. with a treble block. When the load exceeds 20 000 kg., the crane is balanced by a counter weight. Using the turning gear, two men can easily swing the crane with the weight of the load and the balance weight.

The foundation of the crane consists of concrete. The crane is fixed on a heavy iron sole-plate, and is protected by an iron casing. It is guided at the top in a collar-plate firmly anchored in the masonry.

The cranes under No. 8 require two men, in order to lift the maximum load. By means of a special arrangement the wheels can be thrown out of gear and the chain raised rapidly. By putting his weight against the jib one man can swing the crane. Some of them are provided with swinging gear. The projection and lifting height of the steam cranes, as mentioned under No. 13, were increased.

Deeper harbors were required, especially for transatlantic liners, necessitating the construction of cranes having a greater lift.

The beam of vessels was also in proportion to the increase in their size, so that the projecting jib of cranes had to be increased accordingly. For this reason the new steam cranes were provided with a jib of 9.8 m. (32 ft.) instead of 6.8 m. (22½ ft.), and a lift of 13.75 m. (45 ft.) instead of 10.3 m. (34 ft.), as in those first built.

The top of the jib was raised to a height of 8.15 m. (26¾ ft.), this, however, reaching the extreme limit, as with a further increase a raising of the shed roofs would be necessary, to allow a free swinging of the cranes below them, and consequently this would very much interfere with the dry storage of goods by readily exposing them to rain and unfavorable winds.

The lifting speed of the cranes was 1.15 m. (3¾ ft.) per second, and with a speed of 1.2 m. (4 ft.) the safety valves of the hydraulic check cylinders would be brought into action.

The steam crane mentioned under No. 20 was an object of trial, having been previously altered from the original construction. It was a one-cylinder steam crane, retaining the principle of the set of pulleys.

In place of the hydraulic check cylinder, a friction brake was introduced, which was so designed that it worked automatically if the velocity of the lifting chain overreached a certain limit. It was in-

tended to simplify the construction of the crane and to avoid the inconvenience of draining the water, which was necessary during cold weather when the crane was not in use, in order to prevent any damage through frost. No alteration was made in the bogie or in the turning-gear; the advantages gained by this construction were, however, of no great value, and did not balance the disadvantages which arose in the working through the introduction of a second system. The 15 steam-cranes described under No. 25 and No. 26 were required in augmenting the working material. The length of vessels calling at Hamburg was constantly increasing, and the number of hatches increased in like proportion. The earlier ships had only two hatches; whereas, in modern vessels four hatches are very often arranged. In the interest of a speedy despatch it became necessary to work all hatches at once, thus necessitating an increase in crane material.

The ample supply of cranes for the quays which followed materially furthered a quicker despatch of vessels.

But the transfer of the discharged goods from the quay-sheds into the railway cars, which were placed behind the sheds, was found difficult to perform. Owing to the growing activity it became necessary to have suitable lifting gear. The use of the railway track, situated in front of the quay-sheds parallel to the crane track, was to be avoided as much as possible, and for this reason the transport to the back of the sheds and into the cars had to be facilitated. For this purpose wall cranes were arranged (see under No. 29) close to the back of the shed, with a lifting power of 2 500 kg. The cranes arranged in the modern sheds, having no massive walls, were placed on separate foundations and were held at the top of the crane post in strong iron bands connected with the walls. The lifting gear was arranged so as to allow a change in the lifting, having one set for heavy goods and another set for lighter goods up to 750 kg.; the heavier goods to be lifted by two men, and in all the other cases the cranes to be worked by one man only. These cranes are of particular advantage when the cars are to be filled with light goods at great height, such as wool, etc.

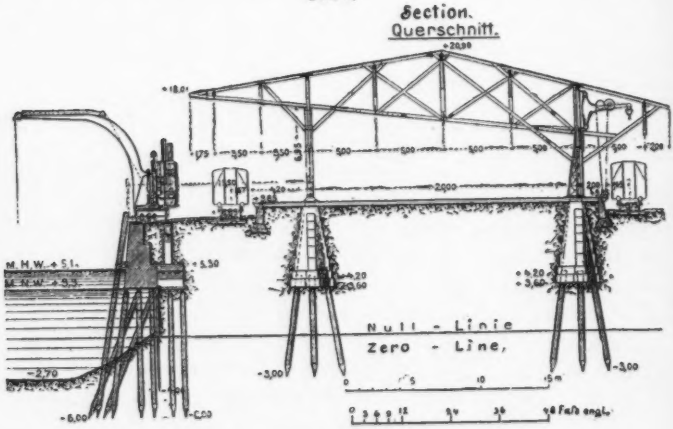
The reduced amount of trade material furnished in the years from 1885 to 1888 corresponded with the building of quays then projected and begun, being the consequence of Hamburg's incorporation in the German custom union. At the end of the year 1888, there were in use 117 steam cranes, which number since that time has been rapidly in-

creased. The first quay lines opened for public use in consequence of the incorporation were the Versmann quay and the America quay. These were furnished with 25 and 12 movable steam cranes, respectively, shown under Nos. 32 and 33 (see Fig. 3).

Welded plates were tried for crane boilers, which were afterwards found to give great satisfaction. Another trial was made with two cranes furnished with wire rope instead of chains.

At this time the lack of means for lifting very heavy loads was felt. Even the existing 40-ton hand crane did not suffice, for instance, in shipping heavy gun-carriages and guns. Therefore a steam crane of

FIG. 3.



Schuppen am Versmannquai.

Shed on the Versmannquai.

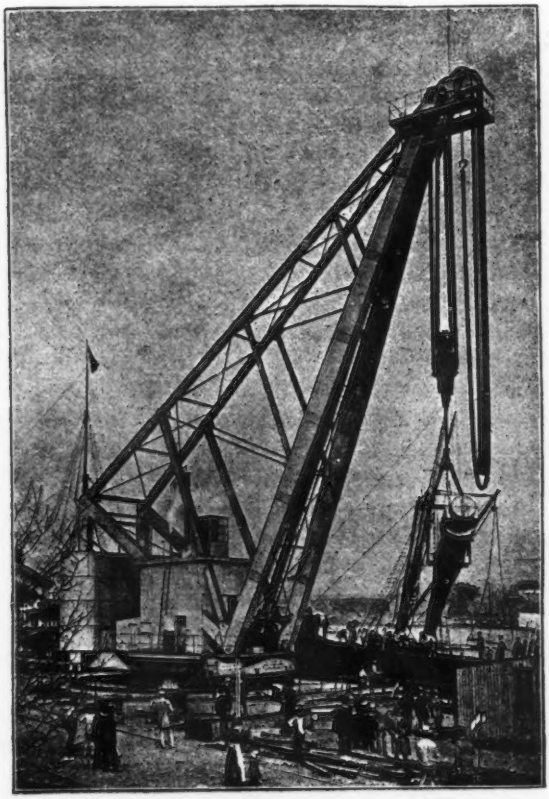
150 tons lifting power was built, in order to meet the growing requirements (see No. 34 of the table, and Fig. 4).

This gigantic crane is the heaviest in use at any European trading port, and is situated at the entrance of the largest harbor of Hamburg, viz., of the "Segelschiffhafen," at a place called Krahnhöft, and is easily reached by ships of any size. The crane is connected with the railway lines, and can be reached by all kinds of vehicles.

The crane swings on a pivot which is fastened to the foundation with eight heavy stays, and moves on 32 steel rollers of 500 mm. (19¾ ins.) diameter and 180 mm. (7 ins.) breadth, traveling on a track of

cast steel; the projection of the crane jib from the center of pivot to the chain being 17.3 m. (56¾ ft.) and 10 m. (33 ft.) outside of the quay wall. The height of the pulley over the top of quay is 31 m.

FIG. 4



150 t-Dampfdrehkrahn am Krahnhöft.

150 tons Steam-Swinging Crane on the Krahnhöft.

(101 ft.). This considerable height was arranged in order to be able to lift or to set up masts of sailing vessels when required.

A ballast tank is arranged, filled with sand, with a total weight of 25 tons; this serves as a balancing weight when lifting.

The boiler and engine are arranged in a separate iron casing of the crane. The boiler has a heating surface of 35 sq. m. (376 sq. ft.) and a working surface of 5 atm. (75 lbs.). The engine is of the double-cylinder type, each cylinder having a diameter of 314 mm. (12 ins.) and a stroke of 550 mm. (22 ins.), and is fitted with a double crank shaft and with Meyer's expansion valve gear. The revolutions are 60 per minute. A flat link chain of steel is used as a lifting chain. The total dead weight of the crane amounts to 230 tons, exclusive of ballast. Weights of 150 tons can be lifted 6 m. (20 ft.) in a quarter of an hour, and one revolution of the crane can be completed in five minutes. The massive crane foundation is based upon 180 piles. The cost of the crane, exclusive of foundation, amounted to about 150 000 marks.

The hand cranes mentioned under No. 35 and No. 36 differ from the former in several respects. First of all, the jib is curved in shape, similar to those of the steam cranes; then, the brake was entirely altered. In place of the iron band-brake there was arranged a centrifugal brake. The apparatus essentially consists of the arrangement of a flying weight (see Plate III), which acts by friction discs, and these act more powerfully the greater the velocity of the weight becomes. By this means a complete and secure regulation of the velocity is accomplished.

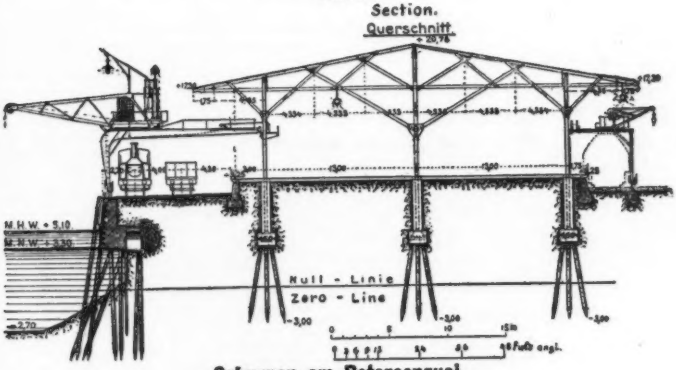
The load remains in uniform motion even if careless handling should cause a sudden accelerated lowering. The driving of the winch is by means of a safety winch handle, *c*, which is always turned in the same direction, being worked either with single or double gearing.

By this means the handling is considerably simplified. Hurling of the winch handle is prevented, also the disengaging of pawls and the shifting of brake levers. By turning the handle the load is lifted; by withdrawing or pressing, it is lowered; and by loosening, it is stopped. The crane-man has only to work the winch handle, and can give his full attention to the motion of the load. In place of lifting chains, wire rope is introduced for these cranes.

For the transport of goods from the quay sheds to the railway car at the back of the sheds, there were arranged for the Versmann quay six wall cranes, shown under No. 37. Contrary to the former wall cranes as furnished to quays, they were built movable. The carriage consists of two separate parts which are arranged one above the other, the

crane-post being fastened between them (see Plate IV). Every part of the carriage is placed on rails, being moved by means of rollers which are conducted along the wall of the shed and securely connected with them. The jib has a section of box form, and encloses the crane post like a mantle. Upon this is arranged the lifting winch, fitted with a safety brake, the latter being of similar construction to that of the hand cranes already described. The winch is worked by a hand wheel and endless chain, and the gear which accomplishes the swinging of the cranes is driven in the same manner. For the lifting of loads a wire rope is fitted. The carriage is moved by means of an endless

FIG. 5.



Schuppen am Petersenqual.

Shed on the Petersenquai.

chain. The motion is received from a chain sheave which is turned by means of a crank shaft.

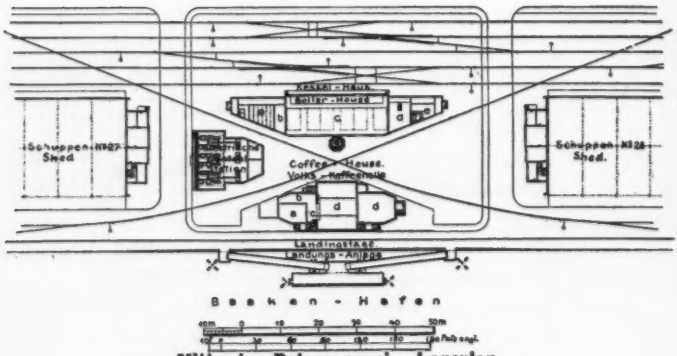
The cranes supplied to the Petersen and Asia quays (Nos. 38 and 39) differ in two respects from the previously described steam cranes.

First of all, the crane carriages received quite a different shape. They were formed in an angle, of which the vertical leg rested upon the quay wall; whereas, the other extends 10 to 11 m. (33 to 36 ft.) horizontally over the top of the road at a height of about 5 m. (16 ft.), being supported at the wall end of quay shed (see Fig. 5).

Here, as well as on the quay wall, rails are arranged on which the crane can travel, having two wheels on each side. Upon the horizontal arm is placed the crane. The main dimensions of the carriage and the crane itself are as follows :

1. Difference in the height of the two rail-levels of the crane track, 5.3 m. (17 ft. 5 ins.).
2. Projection from center of crane to center of lifting rope, 11 m. (36 ft.).
3. Greatest free passage below the crane, 4.95 m. (16 ft. 3 ins.).
4. Projection from edge of quay wall to center of rope, 8.25 m. (27 ft.).
5. Lifting height of the crane for the Petersen quay, 13.75 m. (45 ft.)
6. " " " Asia quay, 18 m. (59 ft.).

FIG. 6.
Plan of situation.
Lageplan.



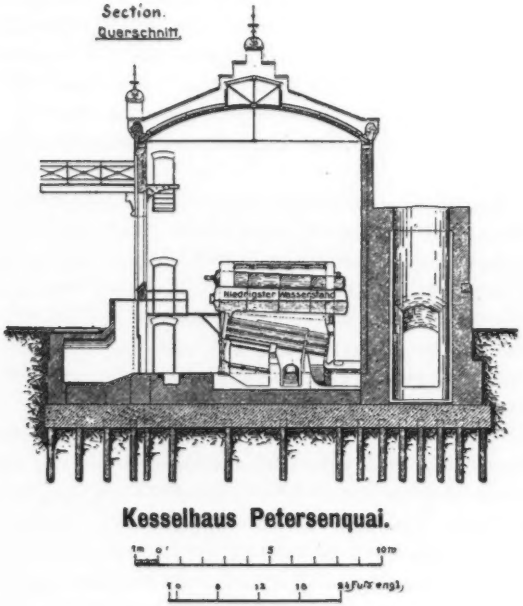
Mitte des Petersenquai. Lageplan.
Centre of the Petersenquai. Plan of situation.

The cranes are not supplied with separate boilers; but the 32 cranes of the Petersen quay and the 27 cranes of the Asia quay are combined respectively with a central boiler station for each, which supply the steam for the cranes.

Both constructions are of the same type and differ only in details. For this reason the following gives the description of the construction at the Petersen quay only. This extends over a length of 1 250 m. (4 100 ft.), and has four sheds, each of which is 260 m. (850 ft.) long. In the center of the quay, between the two middle sheds and parallel to their longitudinal axis, the boiler-house is erected. From this, two branches of steam pipes are laid, each being 625 m. (2 050 ft.) long, to which the movable steam cranes may be connected at any convenient distance of 9 m. (29½ ft.) apart (see Fig 6).

The boiler-house contains six boilers, each having a heating surface of 135 sq. m. (1 450 sq. ft.) (see Fig. 7.) Three of them supply the steam for the 32 cranes and the two 100-H. P. engines which are used for driving the dynamos at the electric station of the Petersen quay. Two of the boilers are for the supply of steam for the engines of the neighboring

FIG. 7.



Boilerhouse.
Petersenquai.

Kirchenpauer quay, to drive the electric cranes, and one is in reserve. As the boiler-room for the six boilers allowed a depth of 9.6 m. (13 ft. 6 ins.) only, it was necessary to introduce water-tube boilers, these being shorter than those with large water space. It was found necessary to introduce a boiler pressure of 13 atm. (195 lbs. per square inch),

in order to maintain a pressure of 10 atm. in the cylinder of the crane which is connected nearest the end of the pipe, at a distance of 625 m. (2 050 ft.).

The general arrangement of the boilers consists of three upper boilers with only one water chamber. The generated steam of all boilers is gathered in a copper receiver of 250 mm. (10 ins.) diameter. The pipes with their branches to both sides of the Petersen quay are connected with this receiver, and can be shut off by special stop valves. Besides these, separate valves of smaller size are connected with the receiver, in order to supply the steam to the auxiliary engines, such as those used for the electric light station, the restarting-injector, and the steam feed pump. All these valves are arranged in the boiler-house.

The steam pipes are conducted over-head on bridges across the railway lines and the road into the quay sheds. The pipes are placed on a gangboard which, in connection with the rail bearers of the crane wheels, is mounted on the columns of the sheds. The steam pipes throughout are of patent welded iron, their internal diameter being at the entrance 100 mm. (4 ins.) and at the end 60 mm. ($2\frac{3}{8}$ ins.). Special care is taken in the connection of the flanges, in order to avoid any leakages whatever.

For this reason the pipes received strong welded iron collars at the ends, these being kept in place by loose iron flanges and bolts, with check-rings between them. The so-called lens-packing pieces are used for check-rings; they are of bronze, and are manufactured in the form of lenses, which are carefully ground into the conical turned seats. Notwithstanding the periodical steam consumption of the cranes, causing violent shocks in the pipe arrangement, these flange connections have given entire satisfaction.

At distances of about 70 m. (230 ft.), there are arranged special water separators, made of wrought iron, and there are two expansion pieces fitted to each side of each separator. Between the separators, the pipes are fitted to small movable carriages, in order to secure a free motion of the pipes in every direction. A steam gauge is fitted to each separator, to indicate the steam pressure at that point. The valves connecting the steam-cranes are arranged 9 m. ($29\frac{1}{2}$ ft.) apart.

In order to prevent the condensation of steam as much as possible,

the pipes, having been heated, were covered with a coat of asbestos 10 mm. ($\frac{3}{8}$ in.) thick. This coat was covered again with asbestos rings of 15 mm. ($\frac{5}{8}$ in.) thickness, 20 mm. ($\frac{3}{4}$ in.) width, placed 50 mm. apart, on this again being laid a close mantle of cork of 40 mm. thickness, served with wire. The spaces formed between the asbestos coat and the cork mantle were filled with a mixture of cork and gypsum. A wrapping of hydrated sulphate of lime was laid round the whole, and this again was mounted with non-conducting material prepared with black japan, and when finished was coated with black japan. This jacket was stopped near the flanges by cast-iron rings. The space between these rings was filled with loose pieces of cork and closed with a divided case of zinc, 50 mm. (2 ins.) thick, filled with cork-stone.

The moving of the frame-formed crane carriage is accomplished by means of hand-gear, so constructed that the two wheels, one being arranged at the water and the other at the land side, can be turned together, or after withdrawing a clutch the wheel on the water side can be worked alone, this being necessary when the cranes are moved through the curved part of the track. The crane carriage is mounted with a turned cast-iron race-ring, on which the upper crane-frame is placed, by four rollers. The frame is guided by means of a steel pin, fitted to the boss of the cast-iron race. A hole is bored in the center of the steel pin, to allow the steam pipe to pass through it (see Fig. 8). One part of the steam crane pipe is fastened to the crane carriage; to this is connected a jointed pipe, fitted at the one end to the above-mentioned main steam pipe and at the other side a small piece is fitted to the steam cylinder, which follows the turning motion of the crane. The stuffing box accomplishing this motion is placed in the axis of the crane.

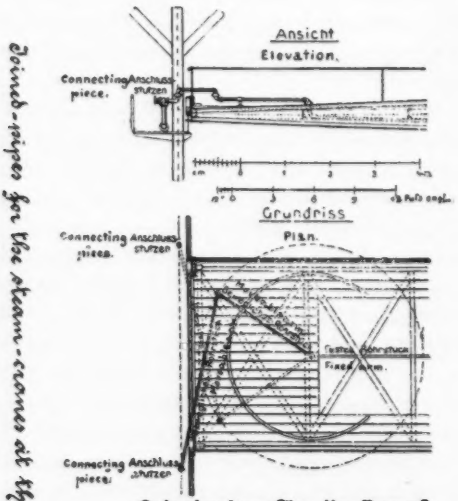
In order to receive an exact result of the efficiency of this central system of crane construction relative to the boiler and pipe arrangement, a series of trials was made in the following manner:

Sixteen of the cranes were tried continuously with the maximum load of 2 500 kg. each, for a period of 9 hours, being supplied with steam from one of the two steam pipes of 625 m. (2 050 ft.) length. Each crane raised the load from the floor of the shed, swung it over the water, deposited it at the water level, raised and brought it back again in the same way. The total lifting height completed during one

turn-play of the crane was about 12 m. (39 ft.), and the total distance swung was about 60 m. (195 ft.). Each crane made on the average 26½ double strokes per hour, but the efficiency of some of them was increased to 40 strokes per hour.

In both boilers kept under steam during this work, 1 kg. of coal evaporated 8.6 kg. of steam of 736 calorics (normal); the utilization of fuel was 70%; the evaporation for 1 sq. m. (10¼ sq. ft.) heating surface per hour was 14.6 kg. and the cost of 1 000 kg. of normal steam was 2.45 marks.

FIG. 8.



Bend-pipes for the steam-cranes at the Petersenquai.

Gelenkrohre für die Dampfkrähne am Petersenquai.

The steam piping condensed 1.55 kg. of water per square meter (10¼ sq. ft.) inside surface of the pipes; the non-conducting covering of these diminished the radiation of heat by 38 per cent. There was no loss of pressure in the pipes when the cranes were not working; when hoisting with 10 cranes simultaneously, for one moment the greatest loss of pressure was 1.6 atm. (24 lbs. per square inch). The mean velocity of the steam in the pipes was 18 m. (59 ft.) per second; when 10 cranes worked simultaneously, the velocity of the steam rose to 30 m. (99 ft.) per second.

The cost of moving one ton of cargo by means of a crane connected with this central steam crane station of the Petersen quay was 0.293 marks in the year 1891. On the Versmann quay, however, where each crane has its own fire, the cost was 0.349 marks. Therefore, one ton of goods is discharged 5.6 pfenniges cheaper on the Petersen quay than on those quays without central steam crane stations. Thus, in spite of the high cost of building the cranes, they work more economically.

The building of the central steam crane station on the Petersen quay showed the great advantage which a central distributing station can have in the working cost. On the other hand, the steam pipes showed that there was still a considerable loss of pressure through condensation in them, besides the difficulties of their construction, which had to be surmounted on account of the high pressure and the high first cost. Then, again, the heavy shocks which were produced in the pipes by the periodical taking away of steam by the cranes made careful working a necessity.

These circumstances caused the use of the electric transmission of power to be considered, especially as cables are not only much cheaper than pipes, but also because the loss of power can be reduced at will by altering the section of the cables. Then, again, cables can be laid above or under the ground in a very simple manner, without pipes and without the necessary bridges across streets and railways which pipes require.

A further advantage was expected in respect to the economical use of power when electro-motors were introduced for the cranes, principally because an electro-motor automatically takes a quantity of electricity sufficient for lifting or lowering the load.

As up to the year 1891 nothing was known of electric cranes suitable for the conditions of the Hamburg quays, it was decided for the present to build two trial electric cranes (No. 52 of the table) before providing the whole length of a quay with such cranes. As there was a central station for electric light on the Petersen quay, the size of which was considered ample for the electric trial cranes, these were placed on the Petersen quay.

Both cranes resemble the steam cranes on the Petersen quay in their principal dimensions and in the weight of the load to be lifted. The construction of the carriage differs very little from that of the steam cranes, and they are moved like them along the quays by means of

hand gear. However, the lifting and swinging gear, and also the brake, have been considerably altered on account of the rotary motion common to electric motors.

One crane, construction A, has a winding engine, consisting principally of a treble-threaded worm working in an oil trough, which turns a worm wheel, on whose steel shaft the cast-iron rope drum is fastened. Worm wheel and rope drum are fitted between two strong cast-iron stands, which are fastened to the cast-iron platform and placed as far back as possible in order to act as a counterweight to the jib and the load of 2 500 kg. hanging to it. The tension stays of the jib are bolted to the top of the stands, and the foot of the compression stay to the platform. The pulley for the steel wire rope is fixed at the top of the jib, and is made as large as possible. One end of the wire rope carries the hook, which is provided with a buffer, and the other end is either wound or unwound on the drum, which has turned grooves to take up the rope. The shaft of the worm is coupled direct to a joined 40 H. P. electro-motor, making 500 revolutions per minute by means of an elastic steel brush coupling. A wedge brake is fitted to the worm shaft and can be worked by the controlling lever; the worm shaft, and therefore, the drum and load, can be stopped instantaneously, and the elastic brush coupling at the same time allows the armature to revolve for a short time, till its energy is consumed. By this means the armature and the different parts of the winding engine are not overworked and damaged. The high threaded worm gearing, whose efficiency after the building of the crane was ascertained to be 70%, has the advantage that the worm turns back of its own accord and turns the electro-motor when the load on the hook descends. However, as the shunt electro-motor, according to its peculiar nature, always remains at its normal speed, it acts in this case, not only the part of a speed brake, but also utilizes the excess of turning power, producing a current and sending it along the wire. Besides this speed brake, which acts by the nature of the electro-motor, there is another special, electric safety brake for cases when the current is interrupted.

It consists of a specially strong brake wheel with a wedge brake, and is fastened to the shaft of the drum next to the worm wheel. The unequally armed brake lever carries on its short arm the brake blocks and on its other arm a weight, which presses the brake into the groove

of the brake wheel. Besides this, there is an electro-magnet under the brake lever which is surrounded by the wire in such a way that it attracts the lever and loosens the brake when the circuit is closed. However, should the current be interrupted in any way, the electro-magnet loosens the brake lever, the brake blocks fall into the groove and hold the drum and with it the load.

The platform of the crane is made hollow and rests upon three wheels, which run on a turned iron ring on the carriage. The starting platform is pivoted on a hollow steel pin, which also contains the wires for the electric current. The swinging gear of the crane is placed inside the platform. It consists of a separate electro-motor of 6 H. P. with a series of circuit closers, which is connected with a worm shaft by a steel brush coupling, and it turns the front or driving wheel of the platform. The motor is provided with a series of circuit closers, in order to drive it at any speed besides the normal speed, which it attains by the velocity of the load of 2 m. There are two levers resembling the starting levers on locomotive engines for the lifting and swinging gear.

The regulating lever of the winding engine acts, not only upon the brake on the worm shaft, but also upon the resistance of starting, and upon an electric switch, which starts, reverses and stops the motor. Besides this, the simple mechanism of a brake wheel turns the starting lever automatically to its middle position and thus stops the whole winding engine, when the attendant releases the slipper handle or the lever handle.

The starting lever of the swinging gear controls the reversing of a Sprague switch, which gives the motor its several directions of rotations. This lever is also connected with a similar brake gear to that of the winding engine. Both levers are worked by one man, and the hoisting and swinging can be done simultaneously by them.

The current is conducted to the crane by means of a copper contact race, fastened to the pillars of the quay sheds. In this way it is possible to put the crane in any position on the quay without having recourse to peg switches, etc., for the cables.

The other crane, construction B (see Plate V), has quite a different winding engine and also different swinging gear to the one described above. Instead of worm gear it is fitted with spur wheels, and the swinging gear consists of a combination of worm and wheel gearing.

The winding and swinging gear are both placed on the cast-iron sole-plate, which carries the wrought-iron jib.

The electro-motor, being the heaviest part of the winding engine, was placed quite at the back, to balance the crane. The motor makes 500 revolutions per minute, and transmits its movements to the drum by means of a pair of geared spur wheels with inclined teeth.

The great circumferential velocity of the drum necessitated the use of rope driving with a movable pulley, which has the advantage of a thin wire rope and a short rope drum and brake. A safety brake is fitted with a special brake lever which stops the load at once when the attendant carelessly lets go the lever, or if an interruption of the circuit should suddenly take place. It consists principally of a brake sheave fitted to the drum shaft and jammed by a balanced weight lying between two brake blocks. When the crane is not working, the rope barrel is automatically thrown into gear with the jammed brake wheel; whereas, when the load is lifted this coupling disengages itself.

The starting platform of the crane rests with four wheels on a turned iron race ring, fastened to the carriage. The swinging gear is on the starting platform between the large spur wheel and the brake wheel and below the rope barrel. On the shaft of the electro-motor with its series of circuit closers is a worm which drives a horizontal worm wheel. A vertical shaft, whose bottom end passes through the platform, carries at its end a spur wheel, which is geared to the inside teeth of the ring on the carriage. The platform has, like the crane described above, a steel pivot in its center, through which the wires of the motor pass.

For working the crane there are three levers, so as to have the same arrangement as on the steam cranes. One is for lifting, one for the brake lever (used at the same time for lowering the load) and one for swinging. The lifting and brake levers are to the right and the swinging lever to the left of the attendant.

By moving the lifting lever forward the load is raised, and by moving it backward the load is held fast. The same movements have to be made with the brake lever for lowering and holding the load. In order to let the electro-motor work as a generator of electricity and send back a current along the wire when lowering the load, the lifting lever has to be moved forward after the brake lever. In order to hold the load again both levers are turned back again. In all these movements the

starting resistance alone is controlled by the lifting lever and the switch by the brake lever.

By means of this swinging lever ensues, at the same time, the connection of the electric motor, and of the resistance as well as the change of connection.

The lever is in its middle position when the crane is not working. By moving it forward or backward the motor is reversed by changing the poles of the magnets, and the several turning directions of the armature are accomplished in this way. Contrary to the crane described first, the connection with the main cable is made by peg switches, and the free ends of both crane cables are joined to the main cable in special closed boxes at a distance of 9 m. from one another.

The crane, construction *A*, has been working for one and a half years, and the crane, construction *B*, for one year. They have proved successful during this time, especially in periods of severe frost, when they showed the advantage of their dry working over the steam cranes. Before the cranes were used they underwent a large number of trials, the results of which are tabulated in the diagrams. With a maximum load of 2 500 kg. every crane worked three hours continuously and completed 45 double strokes. There was no heating of the machinery in any of the cranes.

It follows from the diagrams of current consumption that the current produced by the load, particularly in loading, viz., in moving the goods from the quay sheds down into the hold of the ships, was very strong and that there was a saving of current of over 50% (see Plate VI). When it is considered that two-thirds of the goods discharged from ships at the quays of Hamburg are moved again on lighters, the importance of this return current for cranes, worked from a large central station, will be clearly seen. As a rule, a certain number of cranes are loading, and on the other hand the others are discharging at the same time. In this case the return current produced by the loading cranes flows directly to those discharging and discharges the dynamos in the central station. Accumulators are placed on the Petersen quay in connection with the electric station. They are charged when the two electric cranes are working. The return current produced by the cranes is used in the smaller works to relieve the dynamos charging the accumulators.

It will be clear from the foregoing description that the dynamos can

be made smaller, and that there is a great saving in building and working expenses with these cranes compared to the steam cranes of the same efficiency.

The semi-arch hand cranes shown under Nos. 45 and 46 are fitted with disengaging gear, in order to accomplish a quicker lifting of the vacant hook. These cranes work with wire rope. There are arranged corrugated sheet-iron cabins for the attendant working the semi-arch cranes, to protect him from wind and weather. These shelters are not required for those cranes which are arranged at lower places of the earlier quay constructions. The semi-arch cranes No. 47 were arranged in place of the wall cranes previously in use. They throw a bridge across the railway track.

All wire ropes are worked with a factor of safety not less than six. They are fitted with lift guards, in order to prevent jamming with the top pulley of the jib.

The steam cranes shown at No. 53 have boilers made of mild Siemens-Martin steel.

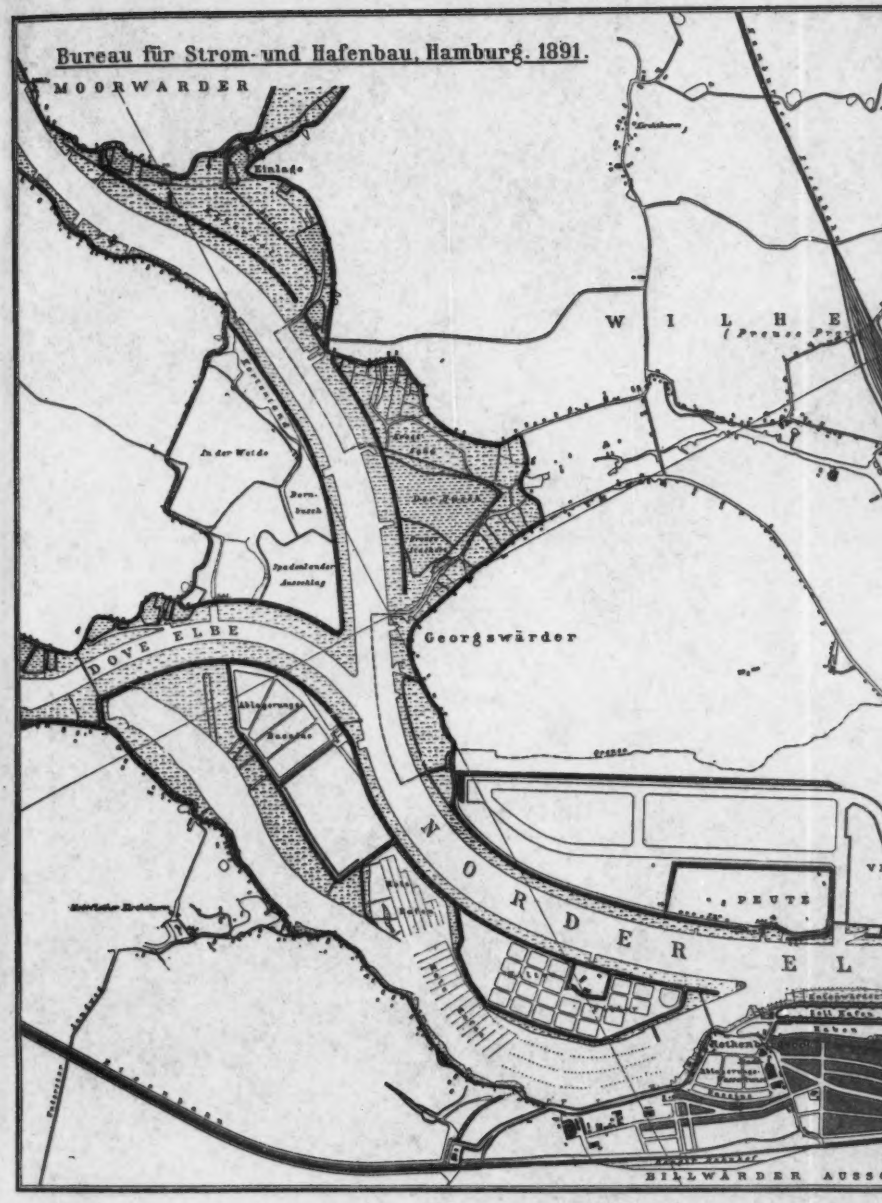
The semi-arch steam cranes shown at No. 54 were fitted with automatic weigh bridge and with regulating gear. These self-acting apparatus have proved very successful, having been previously supplied to cranes. The weight of a semi-arch crane amounts to about 35 tons.

The steam crane No. 55 was furnished both with an iron band brake and a patent centrifugal brake. The latter comes into action only when there is neglect to duly use the former. The crane works by means of a rope, and is moved by the driving gear of the engine.

The 50-ton steam crane No. 56 is a turning crane fitted with balanced weight for the load to be lifted.

The crane rests on 16 rollers, which are connected to each other by means of side levers, so that eight rollers always receive approximately the same pressure, the maximum load for each roller being 24 tons. The crane is fastened to the foundation with grappling irons and turns round a pivot and swings through a whole circle in both directions. Loads of 25 tons can be lifted at a speed of 1.8 mm. (6 ft.) per minute, and loads up to 50 tons can be lifted at half that speed.

Boiler, engine and lifting gear are directly connected to the crane. The boiler has a heating surface of 10 sq. m. (108 sq. ft.), the engine being a vertical twin-engine with double-crank shaft. The diameter of cylinder is 210 mm. ($8\frac{1}{4}$ ins.) and the stroke 314 mm. ($12\frac{3}{8}$ ins.).


Bureau für Strom- und Hafenbau, Hamburg. 1891.
MOORWARDER
Einlage
In der Wolde
Dorn-busch
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DOVE ELBE
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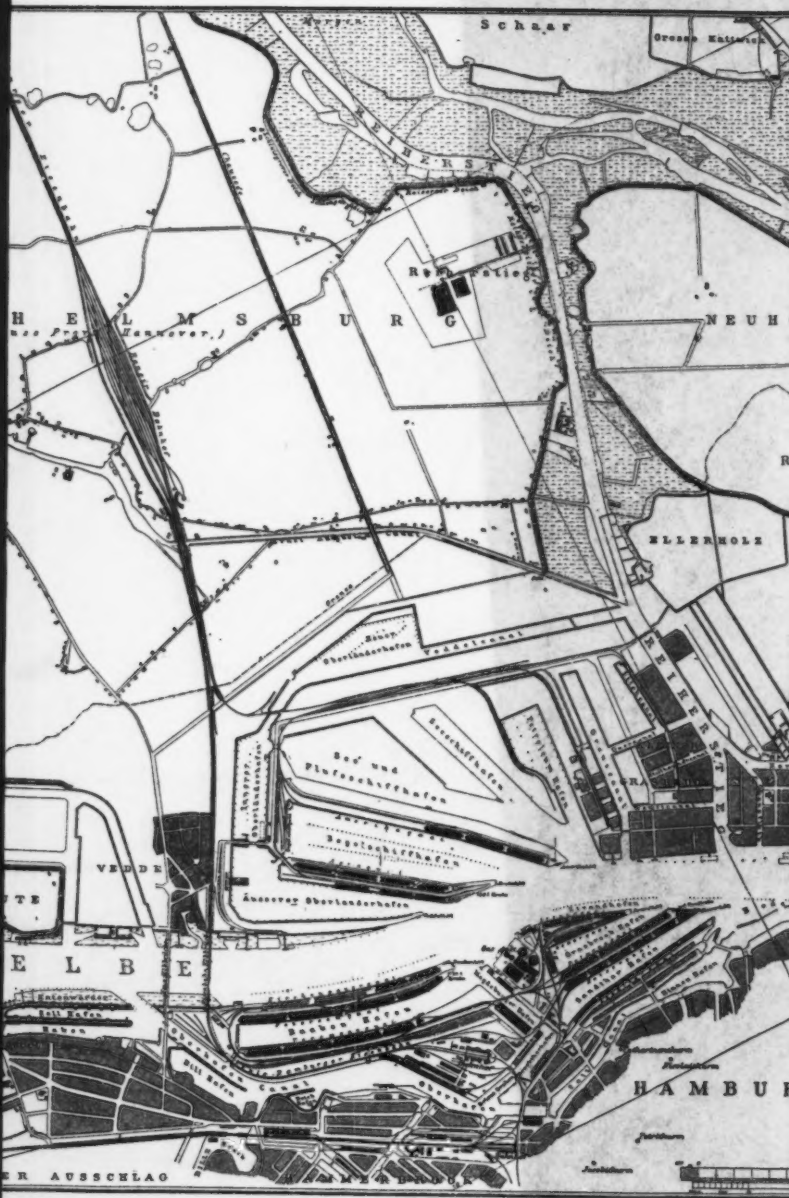
Ablagerungs-Bassins
NORDER ELBE
PEUTE
Rothen
BILLWÄRDER AUSS


Schaar
Grosses Kattenloch
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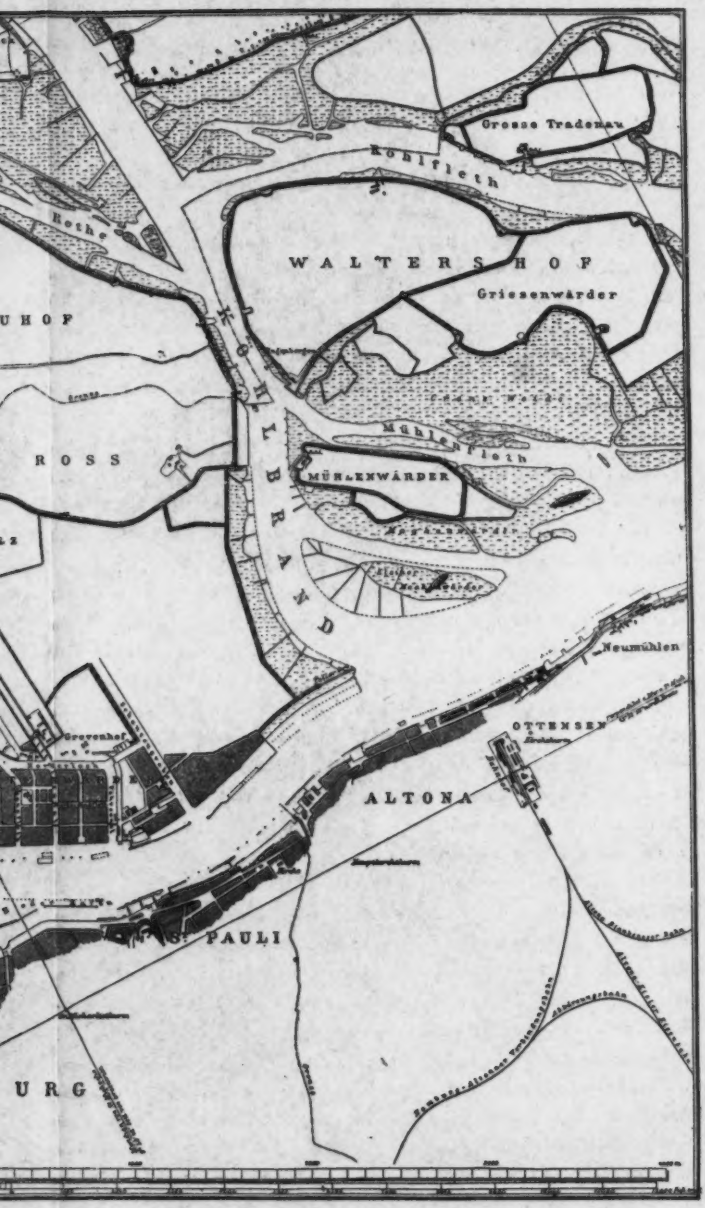
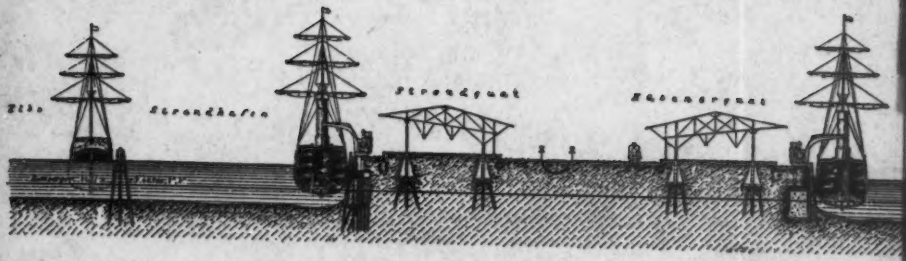

Grosse Trademan
Rothe
WALTERS HOF
Griesenwärder
ROSS
MÜHLENWÄRDER
Neumühlen
OTTENSEN
ALTONA
ST PAULI

Section
Querschnitt



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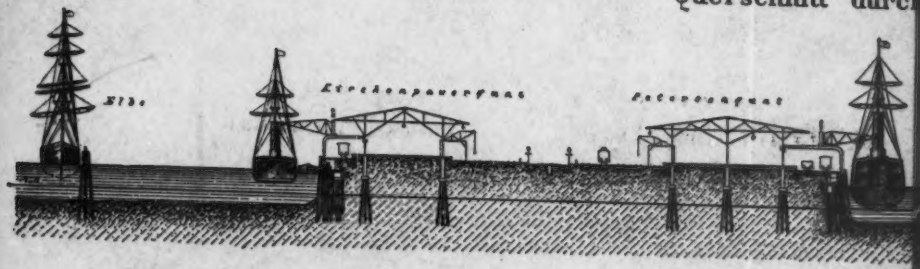
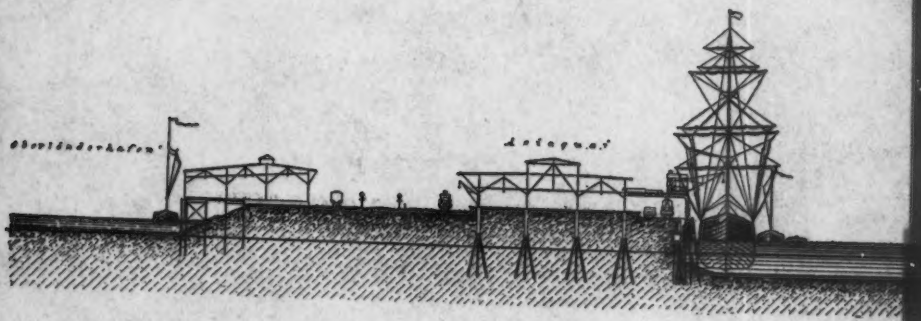
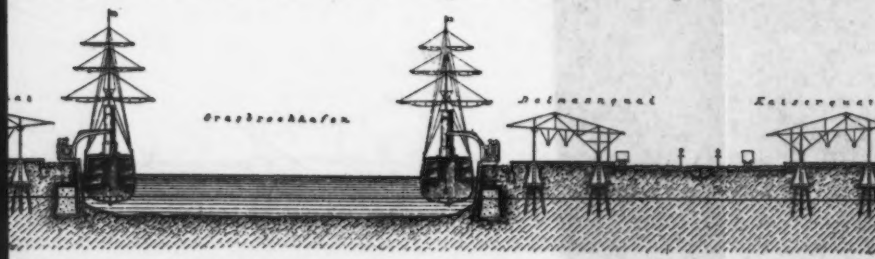


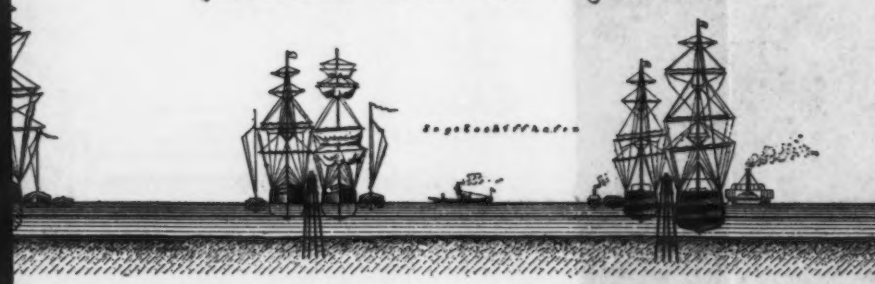


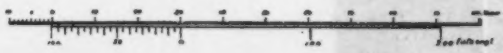
Section through the Quays at the „grosen Grasb
uerschnitt durch die Quaianlagen auf dem grosen Grasb



on through the „Baakenhafen".
chnitt durch den Baakenhafen.

Section through the „Segelschiffhafen."
Querschnitt durch den Segelschiffhafen.





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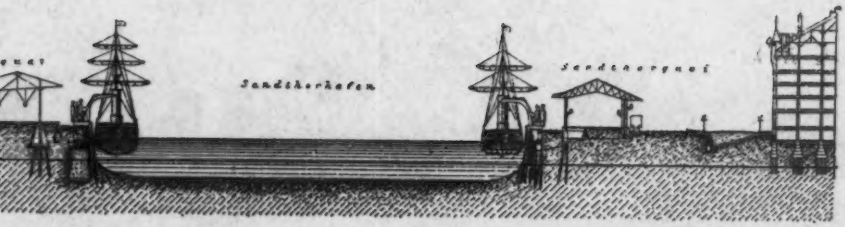
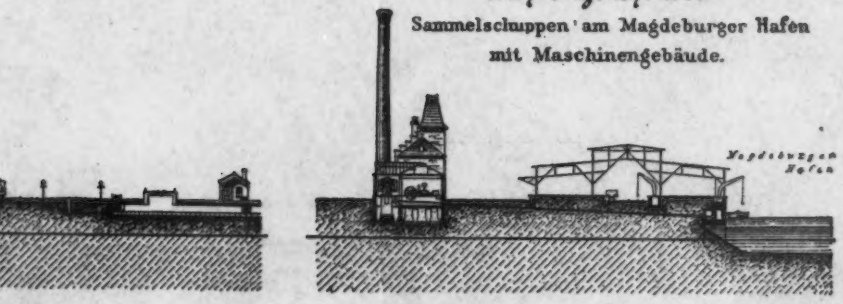
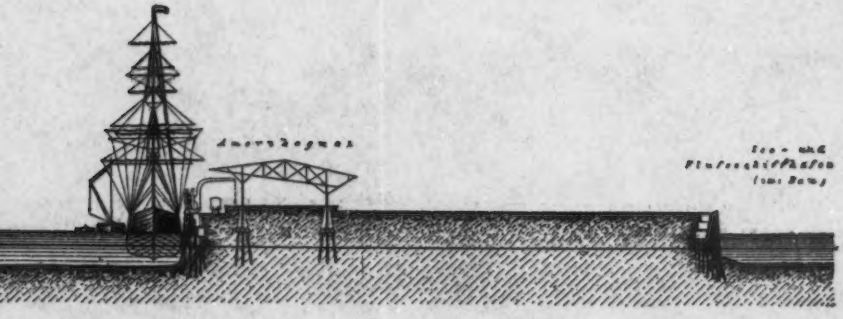


Central sheds at the Magdeburger Hafen with Enginehouse.

Sammelschuppen am Magdeburger Hafen mit Maschinengebäude.

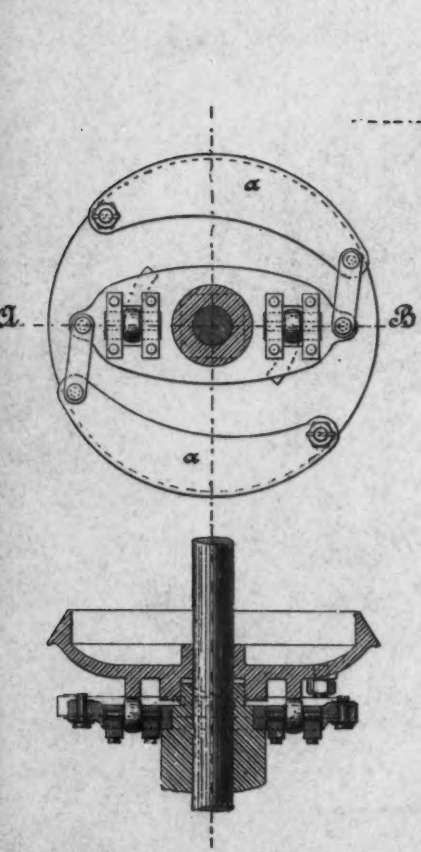


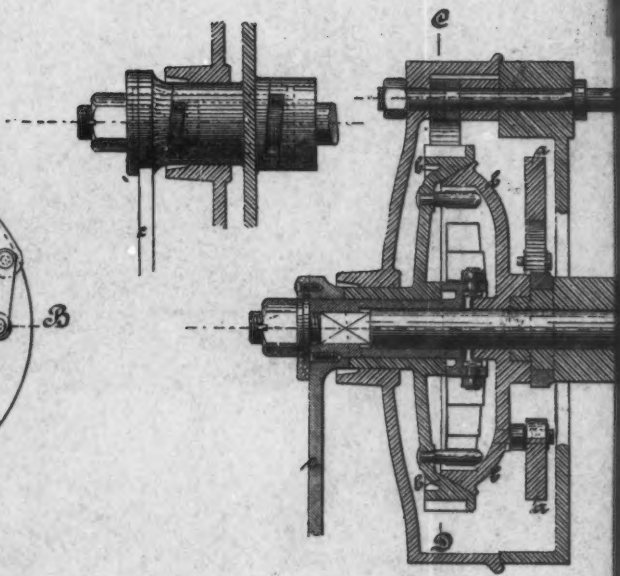


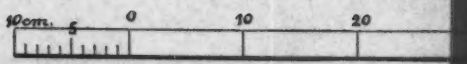
a.

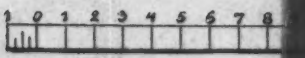
Sicherheitskurbel mit Centr

Safety crank with Centrifu







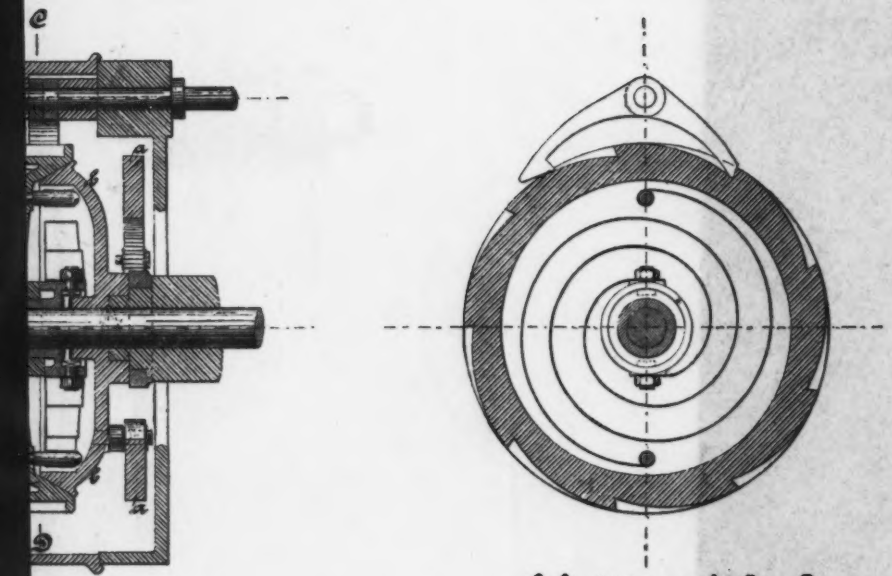


Schnitt nach A-B.

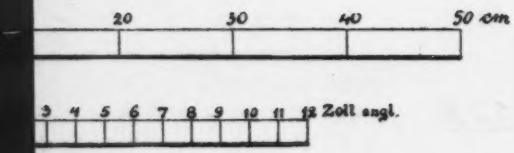
Section A-B.

...mit Centrifugalbremse.

...th Centrifugal-brake.

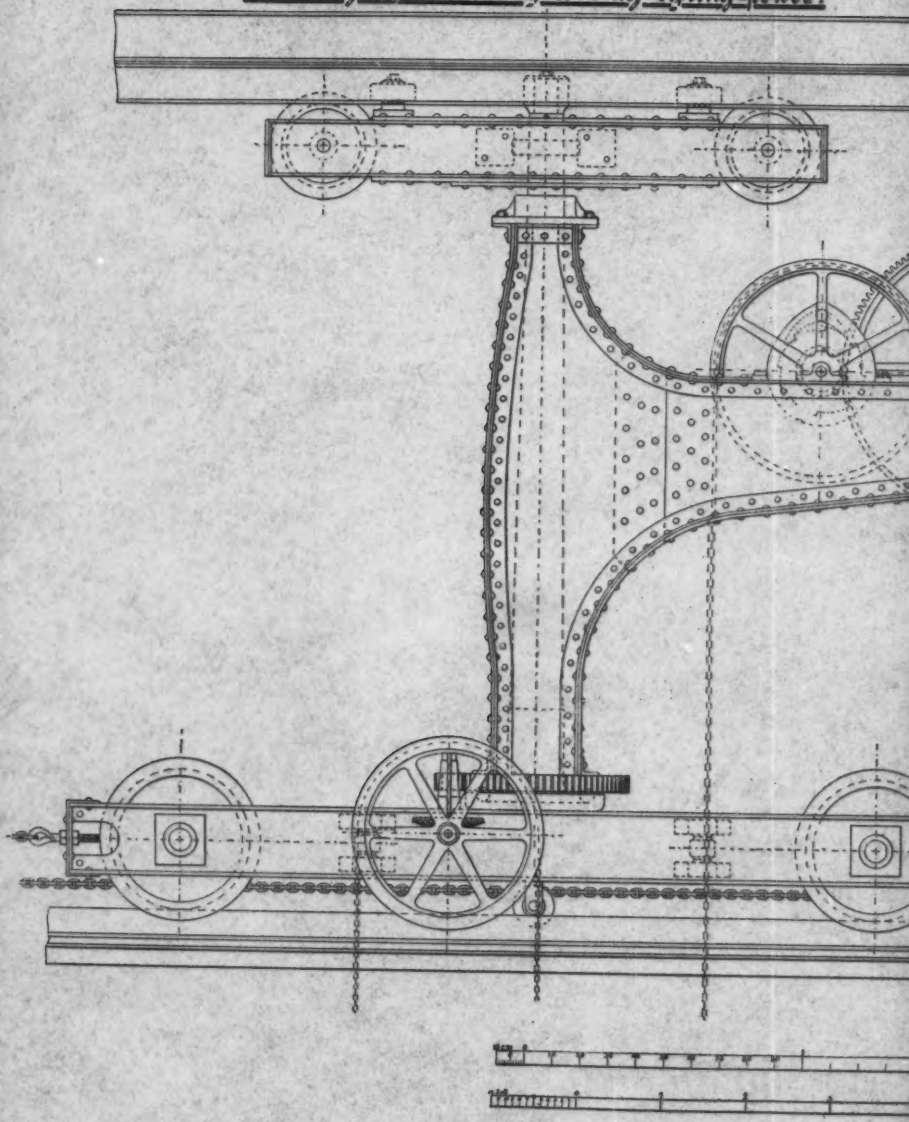


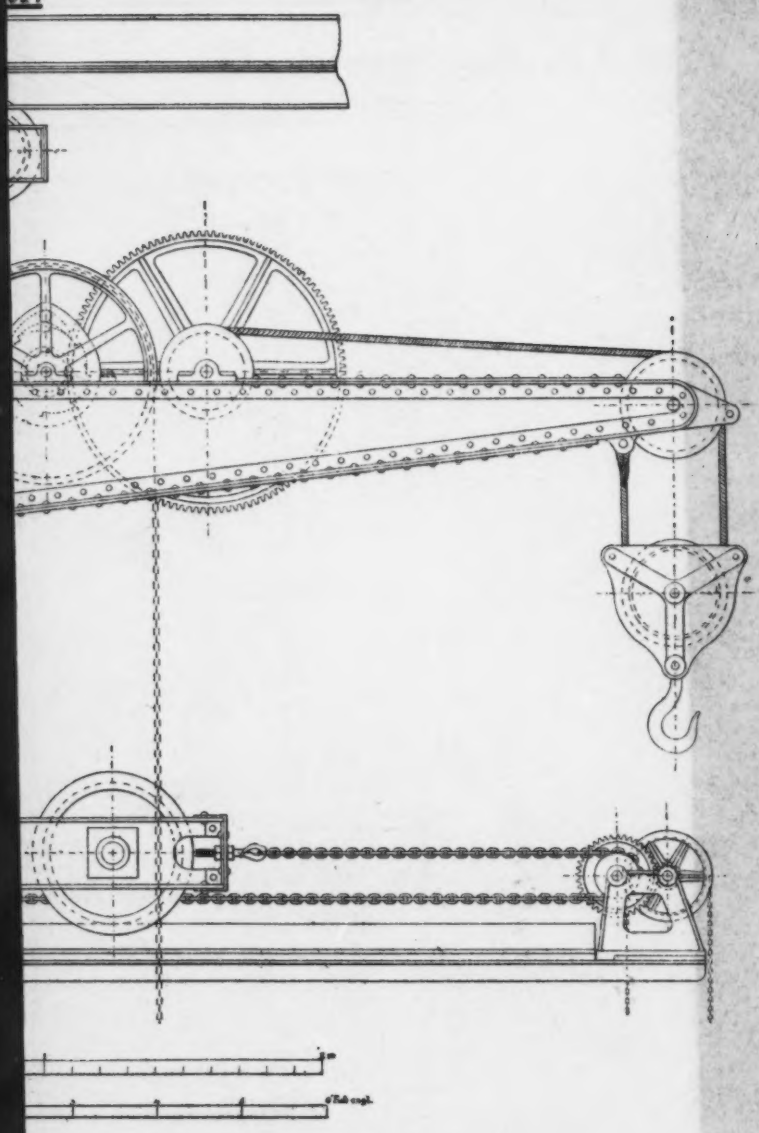
Schnitt nach C – D.
Section C – D.



Fahrbarer Wandkrahn für 2500 kg Last.

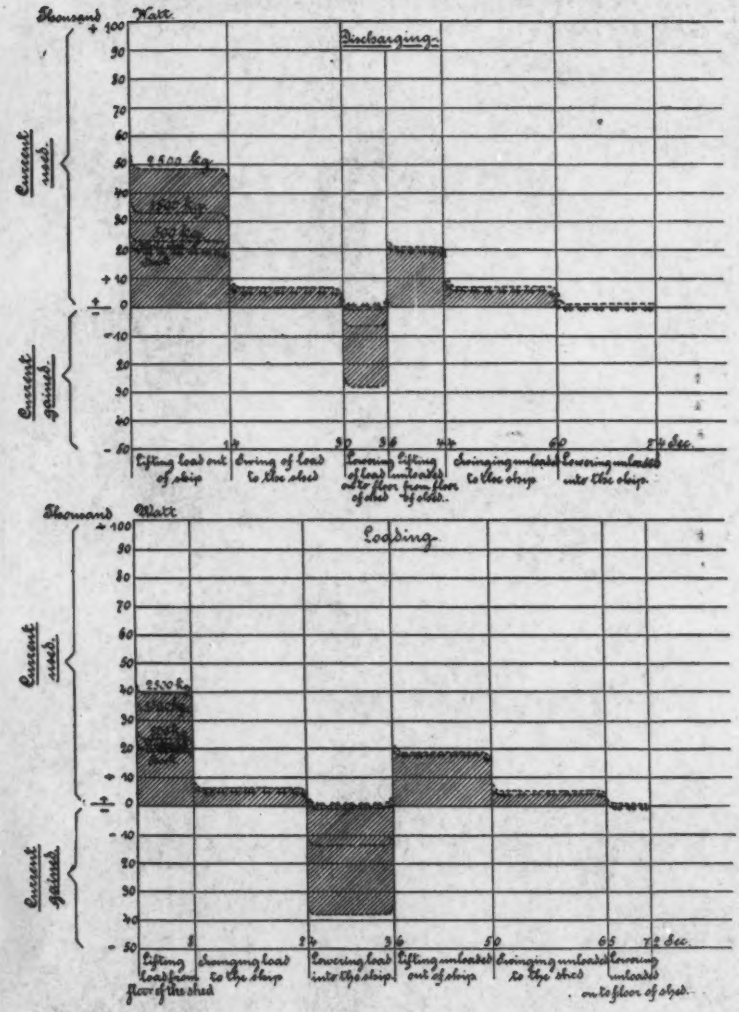
Travelling Wall-crane of 2500 kg Lifting-power.





Electric Crane. (Construction B.)

Diagram of a complete double Stroke.



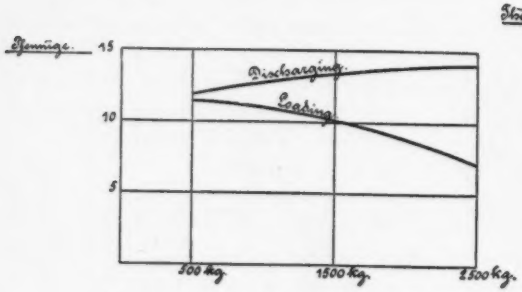
Ele
of 2500 kg
Diagrams

Remarks:

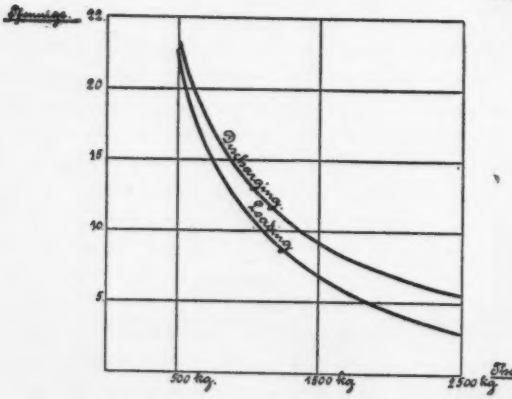
Electric Swinging-Crane.

of 2500 kg Lifting-Power on the Petersenquai. Diagram of

Diagrams of the Cost of Coal per hour for the Load.

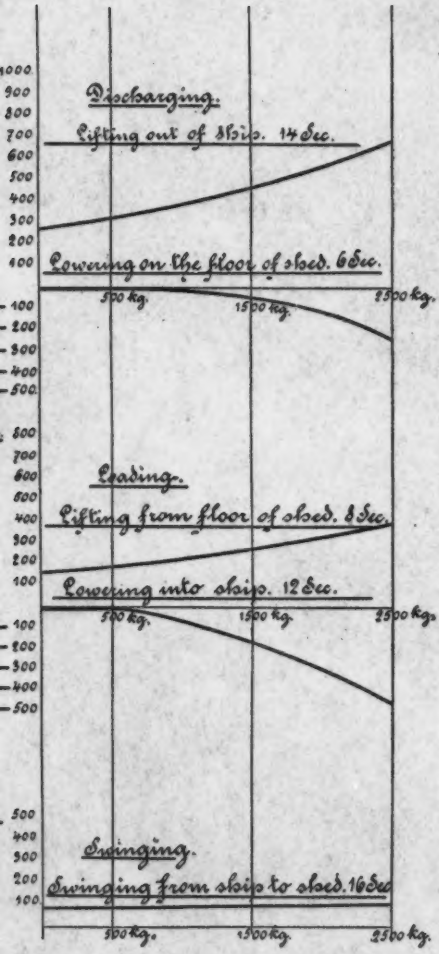


Diagrams of the Cost of Coal per hour for 1 ton.



Remarks: When making the diagrams of the cost of coal it was taken for granted that one cranemakes 24 double strokes per hour.

of the single Movements of a double Stroke.



The engines work with Fink's expansion link motion. Weston's patent brake is fitted, in order to prevent untimely lowering of the loads; this does not offer any resistance by lifting, but will be put into action by lowering. The loads are lifted with wire rope. The cost of the crane amounted to 81 000 marks.

These are all of the crane constructions which have been completed up to the year 1892.

It will be seen from this communication that all alterations in the construction have been avoided as much as possible, both with the steam or hand cranes. Only absolutely definite improvements were taken into consideration which were found necessary during working. The more variations that are made in the construction, the more difficult it will be found to carry on the repairs and to furnish the necessary compensations.

In future the furnishing for the new harbors now in course of construction will be accomplished in the same manner, partly consisting of steam cranes constructed on the same principle with a set of pulleys and hydraulic check cylinder, and partly of electric cranes.

There exists no inclination for hydraulic cranes, as they are endangered during the winter time through frost. The few cranes of this type at present in use are situated almost exclusively at protected places. The climate of Hamburg does not seem to be favorable to this kind of motor, although it is not to be overlooked that these cranes possess advantages in having simple gearing, and consequently there is very little cost in repairing them.

For the reason above given, electricity and steam will be the future motors for the crane constructions of Hamburg.

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646.

(Vol. XXX.—November, 1893.)

METHOD USED TO SECURE THE STABILITY OF A QUAY WALL AT THE PORT OF ALTONA, ON THE ELBE, IN GERMANY, WHICH HAD SHIFTED ITS POSITION AFTER COMPLETION.

BY BERTHOLD STAHL, Stadtbaurath at Altona, Germany.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

Altona is situated on the right bank of the River Elbe, just below Hamburg, and closely connected with that town. It has 150 000 inhabitants, who earn their living by the commerce and industry of the town.

The old-fashioned quays were not adequate to the needs of commerce and the rapidly developing fishing trade, which for the last few years has been in a flourishing condition. The depth of the harbor was not sufficient for steamers of great draft, so that the latter were

NOTE.—Discussions on all papers presented to the International Engineering Congress will be published simultaneously in the number for December, 1893.

obliged to discharge their cargoes into lighters at some distance from the harbor. For two reasons it was out of question to think of deepening the harbor so that ocean-going vessels could be moored alongside the quays and loaded or discharged there. First, the foundations of the old quays were not deep enough to give the necessary depth of water at their sides; and second, the warehouses on the quays reached to the water's edge, so that it would have been impossible to make use of the deepened quays.

In order to get over this difficulty, the town of Altona spent a large sum of money, and bought ground to the extent of 550 m. (1 804 ft. 6½ in.), demolished the private warehouses, erected new quays, with deep foundations, dredged the harbor to a depth of 4.6 m. (15 ft. 1 in.) below the low-water level, and built a railway and sheds on the quays, so that Altona has now a modern harbor, which meets all requirements of the present time.

The discharging and loading at the quays is done by means of traveling cranes, which lift the goods out of the vessels and deposit them in the sheds or railway trucks (and *vice versa*) without any loss of time. The ground on which the quays were erected is very unfavorable, both as regards the kind and the formation of the soil.

The section (Fig. 1) shows the ground, which rises from the Elbe and attains the height of 32 m. (105 ft.) at a distance of about 500 m. (1 640 ft. 6 in.) along the River Elbe. The town is built partly on the slope and partly on the top of this rising ground.

The ground for the quays had to be artificially raised for a width of about 100 m. (328 ft.) (shown at *A* in Fig. 1), and this was protected from the river by masonry above the high water-mark (shown at *B* in the same figure).

The top layers of the ground consist of very fine sand with numerous water-streaks. Below this sand is a firm layer of clay, which rises to the hills at a smaller angle than the surface. The clay is firm when not soaked by water. It is dissolved, however, by the water, and is then a smooth, soapy body, which allows the top layers to slide down.

As long as the water from the hills can percolate freely and without hindrance through the sand, there can be no fear of a catastrophe. As soon, however, as the free outlet of the water is stopped, the body of sand becomes papescent, and the clay becomes lubrical (soapy) on its surface, and landslips occur.

When the wall was built, these facts must have been ignored, or, at any rate, not considered dangerous. The wall was built and constructed nearly on the same lines as the one in Hamburg, but it must be remembered that the formation of soil in Hamburg was quite different, so that although it suited the conditions of the ground there, it did not prove successful in Altona.

Fig. 2 shows the construction of the quay clearly.

The front part of the wall is solid and backed by pillars placed 9 m. (29 ft. 6 in.) apart, center to center, and secured to it. Between these pillars there are arranged two arches (see view from the bank), the bottom one being loaded by sand at the back, and the top one being used as a foundation for a girder to carry the rails of the steam cranes. The rail *R* (Fig. 2) was dispensed with later on, because the front wheels of the cranes run on the edge of the quay and the back ones on a rail on the first floor of the sheds. The cranes are, therefore, semi-arched, and the railway trucks can run underneath them, alongside the quay wall. This very successful system was first adopted at the port of Bremen on the River Weser. The advantages of these semi-arched cranes will be easily discernable. The wall is built of hard bricks and cement mortar (1 part of cement to 4 of sand) and fitted with all the necessary gear. It is built 5.8 m. (19 ft.) above the ordinary water level.

At the lowest ebb tide the crown of the wall is 6.8 m. (22 ft. 4 in.) above the low-water level.

The foundation consists of a pile framing, made of vertical and oblique piles, the tops of which are 8.9 m. (29 ft. 2 in.) and 9.7 m. (31 ft. 10 in.) below the ordinary water level. A tongued and grooved piling is built behind the wall 7 m. (23 ft.) high (see Fig. 3). These piles were driven with very great precaution. The bearing strength of each pile was calculated from the respective depth it was driven in. On the piles is fixed a firm frame, composed of longitudinal and cross beams mortised and connected to one another. Strong boards are placed on these cross beams, which support the wall. The framing is 45 cm. (1 ft. 6 ins.) above the mean water level, so that it could be carefully built above the water-mark, when the water was low.

With the help of this description and the drawing, the following will be clearly understood.

The whole length of the wall (550 m., or 1 804 ft. 6½ ins.) was com-

pleted in two years without an accident; and after filling up the space behind, warehouses (sheds) were built 8 m. (26 ft. 3 ins.) behind the quay wall. These warehouses are light buildings made of corrugated iron, as will be seen in Fig. 1; and the foundations are made so that the wall is not subjected to any lateral pressure from the buildings.

In order to drain off the water of the hill and the street, a drain was laid in the road behind the sheds, and the water was emptied into the Elbe by means of a pipe laid at right angles to the wall (Fig. 4). The drain was firmly secured to the quay wall.

At the beginning of August, in the year 1890, soon after the completion of the quay, cracks were discovered in the wall about 120 m. (393 ft. 8½ ins.) long, which differed from those hitherto found in quay walls in their position, number and size, so that it was at first feared that the wall had not sufficient stability. At the same time it was noticed that the solid gable walls of the sheds placed at right angles to the quay were cracked and giving way, and also that the pillars supporting the roofs of the sheds, and placed on the water side of the same, were not standing vertically, but leaning backwards (to the land side), they were no longer parallel to the lower pillars of the sheds on the land side.

In consequence of the simultaneous appearance of this double phenomenon, it was concluded that, not only the sheds which, as mentioned above, were built on a separate foundation, but also the quay wall itself, had moved forward. It was assumed that the whole earthwork had moved forward, because the pillars at the front of the sheds inclined considerably towards the back, so that their bottom ends had been shifted towards the water, and because the pillars at the back of the sheds had only slightly lost their vertical position. This was proved conclusively by the cross cracks in the drain pipe, placed at right angles to the quay wall. Naturally, these cracks were larger near the wall and diminished in size towards the sheds (hillside).

Without searching for the cause, it was decided to remove the pressure of the earth on the wall without delay, in order to save time. The backing was taken away, so that the wall was laid bare.

Then the front foundations of the pillars of the sheds were secured to the back ones by strong stays of iron, so that the front and back pillars had to move uniformly (see Fig. 1).

It was very soon noticed that the sheds had stopped moving. The

back pillars were bedded in the firm clay which, as has been shown above, rises from the Elbe up to the hills. By means of these stays the influence of the top shifting layer upon the front of the sheds was removed, as the back foundations completely resisted this sliding. In the mean time there was little fear of the wall falling down, as the back pressure had been taken away, and it was now possible to measure the ground periodically, which, together with extensive examination of the soil, would explain the cause of the shifting.

The examination of the soil was accomplished by means of earth-borers and lining the several holes with iron pipes, in order to observe the fluctuations in the rise and fall of the ground-water. The influence of the water from the hill, and its connection with the rising and falling of the Elbe during ebb and flood, were particularly investigated.

First of all, the measurements which were taken with the view of examining the moving of the quay wall, and which had to be made very carefully and very often, will be described.

The following points were determined:

1. The height of the wall crown by leveling. Very little differences were noticed here.

2. The inclination of the wall. In the design, the inclination of the front surface of the wall was fixed at 1 in 10.

By means of an apparatus made expressly for determining the change of inclination, it was noticed that the wall swung gently like a pendulum round a point of the piles, especially in the direction of the water.

3. The most difficult measuring was the observation of the traveling motion of the wall towards the Elbe, and this was done by means of a theodolite. This difficult measuring was rendered still more so by the wall adopting an irregular concave form, and also by the fact that it was always changing its position and therefore impossible to fix the instrument anywhere on the ground. This difficulty was overcome by placing the instrument between two lightning conductors, which were fastened to some high steam chimneys at a long distance, one of them to the west, the other to the east, of the ground to be examined. In this way an immovable vertical plane had been gained behind the wall which was independent of the instrument fixed on the moving ground, and from this plane the distances of the several points

of observation could be measured at any time. In order to prevent mistakes of the instrument entering into the dimensions, it was always fixed exactly in the same position. Then, again, the precaution was taken of having the same engineer make the measurements.

Iron marks were fixed on the crown of the wall, by which means it was possible to place measuring rods in their exact position. The total number of marks was 38, and they were fixed at a distance of 10 to 20 m. (33 to 66 ft.) from each other. Each mark had its own measuring rod marked with its respective number, and, before measuring, these rods were placed in their proper places. The rods carried an iron point at one end, fixed in a vertical position. This point was brought in the plane of sight, and the rod kept always in the same horizontal plane at right angles to the plane of sight. When the first measurement was made, there was fixed on every rod the distance from the plane of sight to the mark placed on the wall, so that, when measuring again, the difference of the first measurement could be accurately read off as soon as the rod had been adjusted. As the dimensions were comparatively small, mistakes could not occur. This method has proved successful during three years' observation and has given reliable figures of the movements of the quay.

It would lead us too far to give a description of the observations made during several years; indeed, it would be almost impossible to show all the tables and graphic representations of all observations in this paper. It will suffice the practical engineer to learn that the data collected showed the cause of the malady and enabled the proper remedies to be applied.

It turned out that the whole body of earth up to the hill above the layer of clay moved towards the Elbe and pressed with such force against the quay wall that the latter was shifted also in the direction of the harbor. However, as the bottom ends of the piles were bedded in the blue clay, a kind of pendulum-swinging round the ends of the piles, took place at first, and this had to be stopped.

This could be done by very long and strong stays, fixed at the top of the pile-construction and connected with the clay hill at the land side. This will be seen from the section in Fig. 3 of the construction, and also Figs. 4, 5, 6, 7, 8 and 10.

Then it was advisable to keep the backing of the wall as light as possible and to have the ground well drained, in order to equalize the

water level of the river and the ground-water level before and behind the wall as soon as possible, and so avoid all unfavorable loading behind the wall and all slipping on the layer of clay where possible.

Before starting this important work, the opinion of the well-known and highly reputed engineer, Herr Ober-Bau-Director Franzius, of Bremen (known in connection with the correction of the Weser), was asked. He agreed with the proposals, and the work was executed according to his design.

The Stays.—In order to secure the whole moving stretch of land to the stays, two thick beams had to be fastened beneath the surface of the water (Fig. 3) in front of the piles, for the purpose of transmitting the pull of the stays to the piles. This difficult task could only be done at low water, and was therefore very slow. At the same time ditches, about 1.5 m. (4 ft. 11 ins.) broad and 5 m. (16 ft. 5 ins.) deep and parallel to one another, were dug between the boards at right angles to the quay wall, at a distance of about 4.5 m. (14 ft. 9 ins.). The water was pumped out by steam pumps. Then a ditch about 5 m. (16 ft. 5 ins.) broad and about 50 m. (164 ft.) from the wall and parallel to it was dug, into which the other pits opened. At the intersections of these longitudinal and transverse ditches, which reached as far as the firm clay, larger pits were made and filled with strong beams of about 2.5 x 2.5 = 6.25 sq. m. (8 ft. 2½ ins. x 8 ft. 2½ ins. = 67.24 sq. ft.) surface, which were supported by the vertical planished front side of clay.

The iron stays were secured between these two points, viz., the outside of the two longitudinal beams placed before the wall and the wooden shield (Fig. 7 and 4) in the clay hill on the bank. These stays consisted of separate pieces (links) 5 m. (16 ft. 5 ins.) long, alternately round bars 8 cm. (3.15 ins.) thick and two flat iron bars of the same strength joined together by a bolt through an eye at their ends, so as to form a chain (Fig. 11). The front link of this chain was first of all pushed from the water underneath the wall and between the piles of the foundation till the front bolt of the stay came in contact with the heavy iron plate resting on both horizontal beams. In order to tighten this chain and the screw behind the shield, the links of the chain were bedded in a closed wooden box, so that in case the earth should slip while the work was in progress it would still not interfere with the mobility of the chain. After all the links of a stay were joined together, a task which often required 3 or 4 weeks, the screw on the

bank was tightened, and in this manner one point of the wall after another firmly secured to the immovable hill of clay.

In all there were fixed 29 stays at a distance of 4.5 m. (14 ft. 9 ins.), and the time spent on the work was about 18 months, which is accounted for by the fact that it had to be done mostly under a heavy rush of water and only at low water. Another great obstacle was that most of the stays had to be passed underneath the finished warehouses.

The Drainage of the Ground.—Besides the method of securing the wall as described above, the draining of the ground behind it was of the utmost importance. First of all, holes were made in the grooved piling under the wall and also in the wall itself at several places and in different heights. Then the bottoms of the ditches, in which the stays were bedded, were filled with stones so that a splendid drain was formed behind the wall from the slope of the hill to the Elbe by which the water could be run off rapidly and without danger. The observations of the water-level made later on, have proved that the object sought has been attained.

The Strengthening of the Quay Wall.—When the quay wall was exposed by the removal of the backing it was seen that the arches (*a* and *b* in Fig. 2) of the wall between the pillars had been totally destroyed. It was not advisable to renew the arches, because the pressure of the earth had unfavorably strained the wall in a vertical direction. Some of the supporting pillars had been detached from the wall and sunk. Itwas now resolved not to load the piles and relieve the pressure from the destroyed wall as much as possible. This object was attained by the following construction:

The soil just behind the quay wall was dug out at low water and partly under water and the space filled again with crushed bricks. By this means the backing was not only lighter, but the drainage could be carried on at a deeper level.

On the top of these bricks and behind the quay wall another wall was formed of lean béton, which was to take up the whole pressure of the upper backing soil by applying the load of it to the grooved piling and to the piles as low as possible. In order to prevent the stays from being strained by the weight of the new wall and the earth, the ditches in which the stays were bedded were arched, so that lasting provision was made for the drainage of the water.

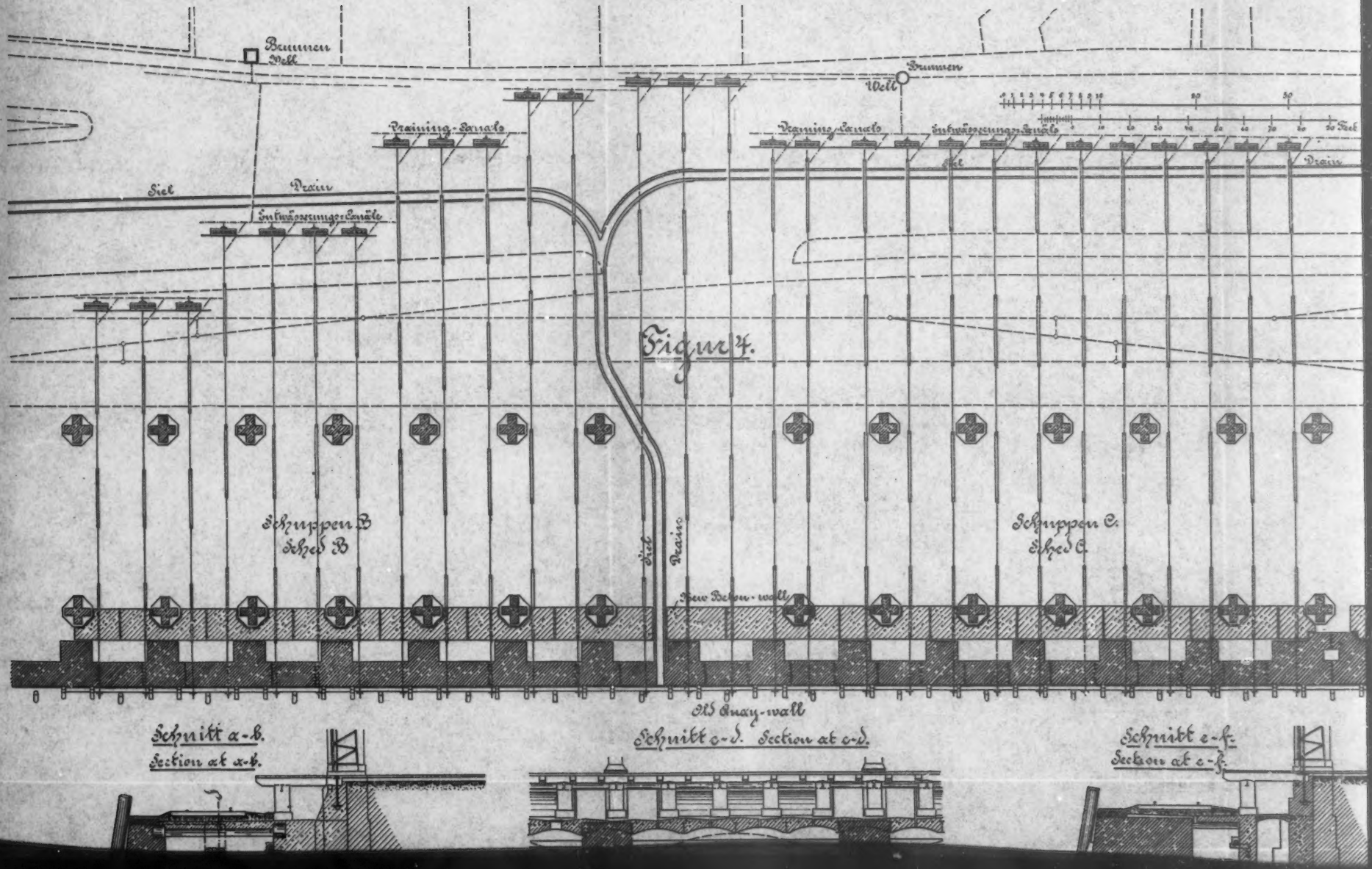
When the béton wall was finished (it will be seen from the drawing

at Fig. 8, *a* and *b*, that the pillars of the sheds projected clear of the profile of the wall), the space behind was filled with brickbats, which could be furnished easily and cheaply from the shelves of the large brickyards on the lower banks of the Elbe. In order to procure a better outlet for the drainage water, earthen pipes were cemented into the béton wall. The front wall was in this way relieved of pressure as far as possible, and had now only to take up the vertical loads, which were produced by the construction of the crane rails, the traveling cranes and the movable loads caused by the railway trucks. The ground for the railway was constructed as follows: the space between the two walls was bridged over by iron I beams, placed about 1.8 m. (5 ft. 10.8 ins.) apart, and these beams were covered with béton covers (caps), so that an empty space was formed between the two walls. This space is accessible from the top, and by means of it the front wall can be constantly observed (see Figs. 3 and 9).

About a year ago the quay was opened to full traffic, and the loads moved just behind the wall and in the warehouses have been exceptionally heavy, but not the slightest change was noticeable in the wall or ground, so that it is expected that the wall has been permanently fixed. The cost of renewing the quays was about 275 000 marks, or 2 000 marks per linear meter (3 ft. 3 4 ins.) of the quay.

Befestigung des gefährdeten Theiles d

Refastening of threatened Part of

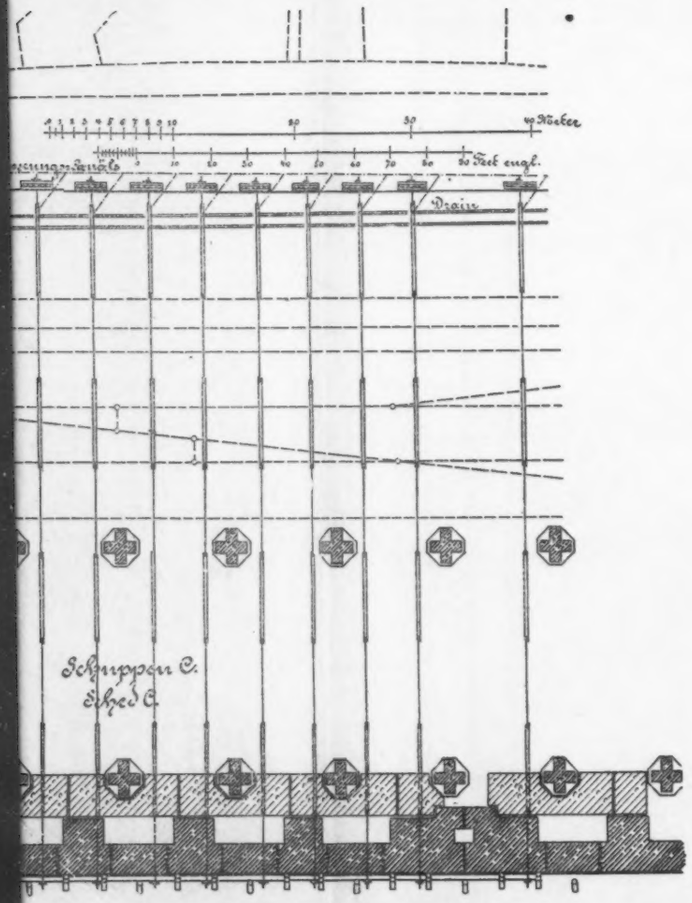


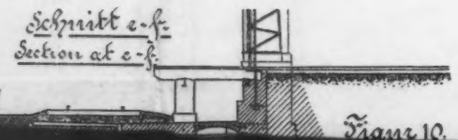
Figur 4.

VOL. XXX, No. 646.
TRANS. AM. SOC. CIV. ENGRS.
STAHL ON QUAY WALL AT ALTONA, GERMANY.
PLATE I.

...ährdeten Theiles der Ufermauer am Ostkai.

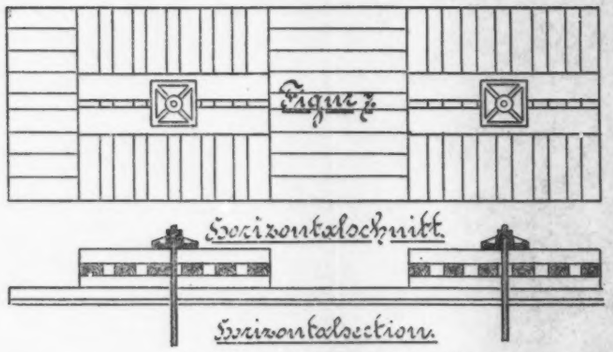
...h threatened Part of the Wall at the eastern Quay.





Figur 10.

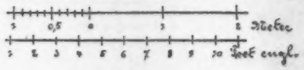
Unterlager an der Landseite.

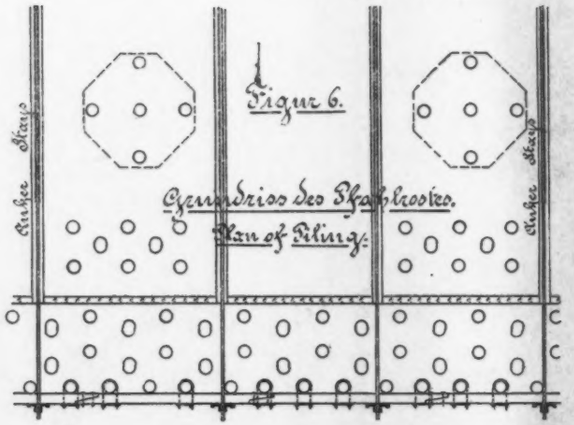


Figur 7.

Horizontalschnitt.

Horizontalsection.

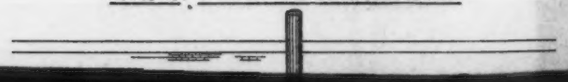




Figur 6.

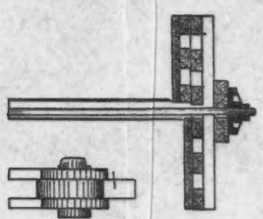
Grundriss des Stahlringes.
Plan of Ring.

Ansicht von der Wasserseite.



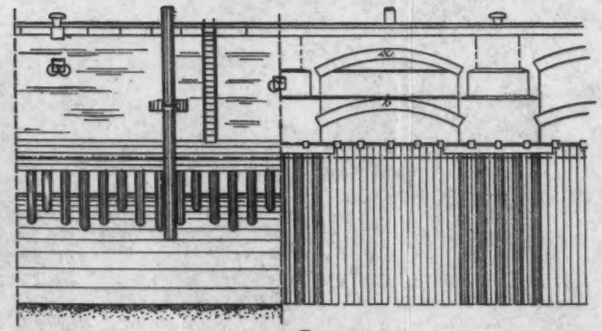
Wooden shields on the landside.

Cross-section.
Querschnitt.

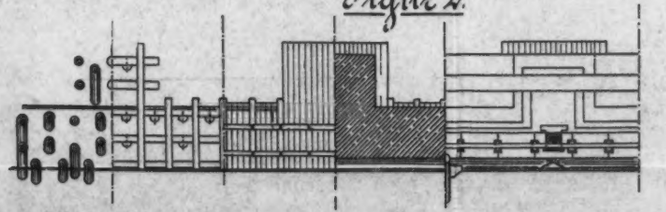


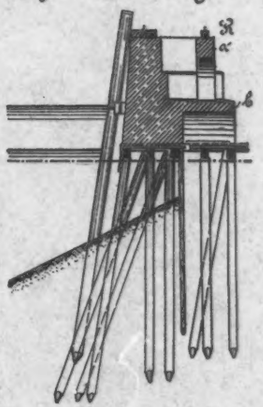
Figur 11.

Zustand vor der Bewegung. Condition before moving.



Figur 2.





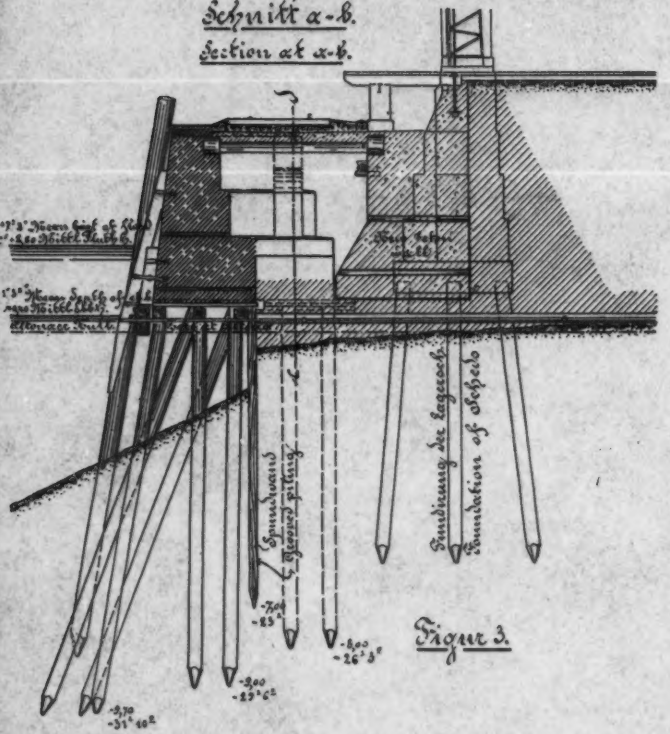
Schuppen B
Shed B

Schuppen C.
Shed C.

New Retain-wall

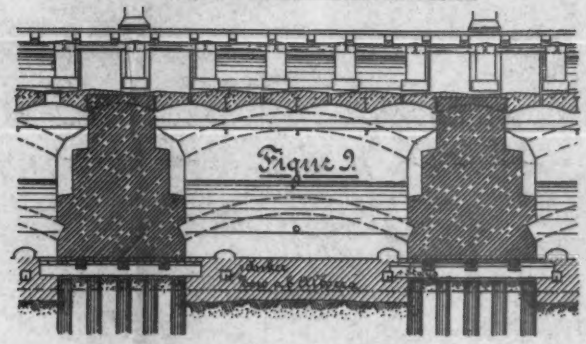
Old Quay-wall

Schnitt a-b.
Section at a-b.



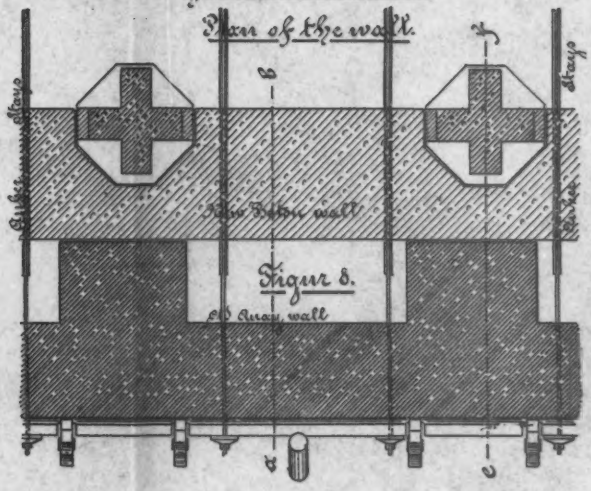
Figur 3.

Schnitt c-d. Section at c-d.



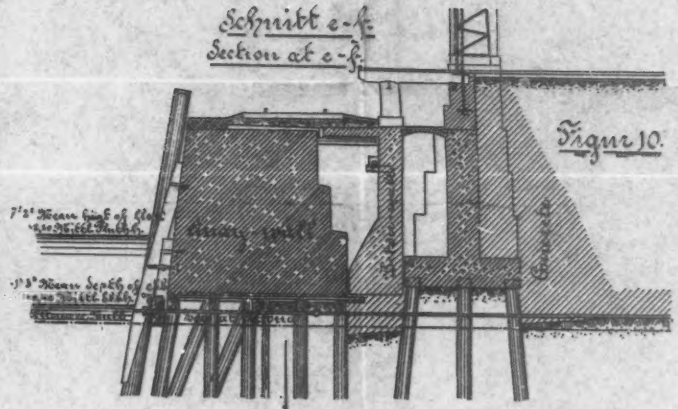
Figur 9.

Grundriss der Mauer.
Plan of the wall.

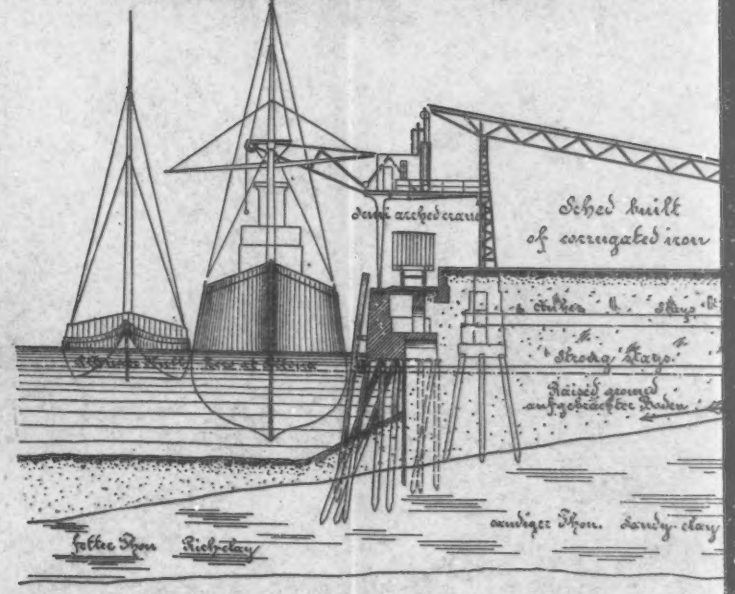


Figur 8.

Schnitt e-f.
Section at e-f.



Figur 10.



Meter
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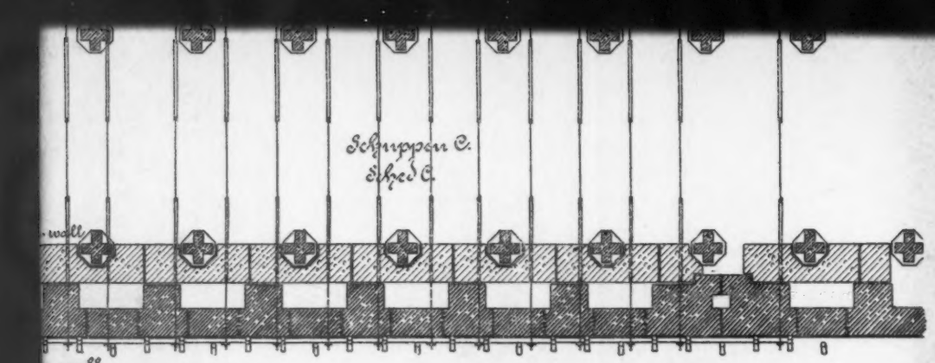
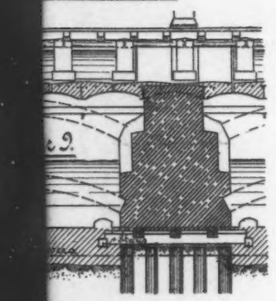
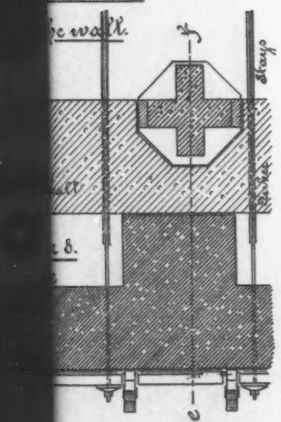
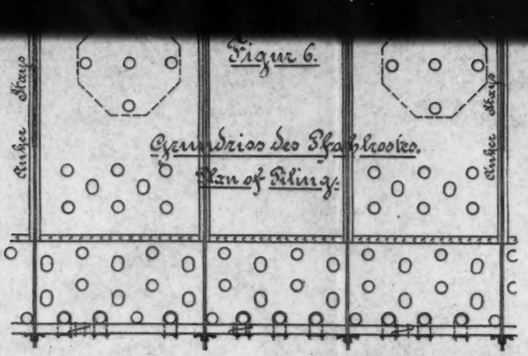
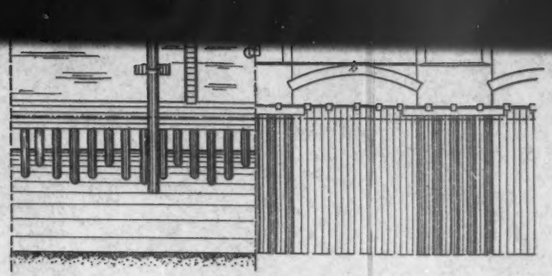
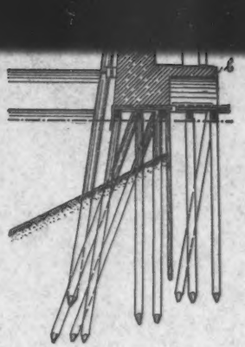




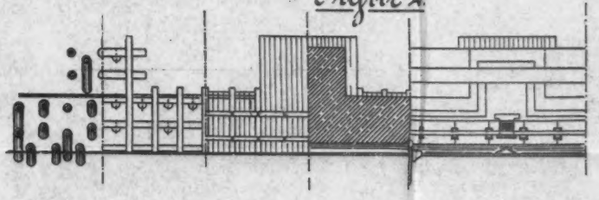


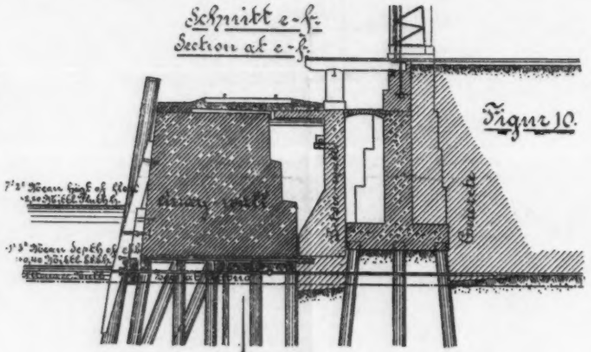


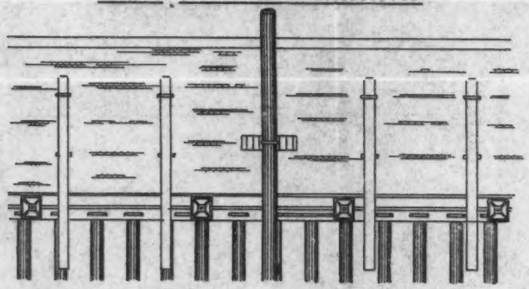




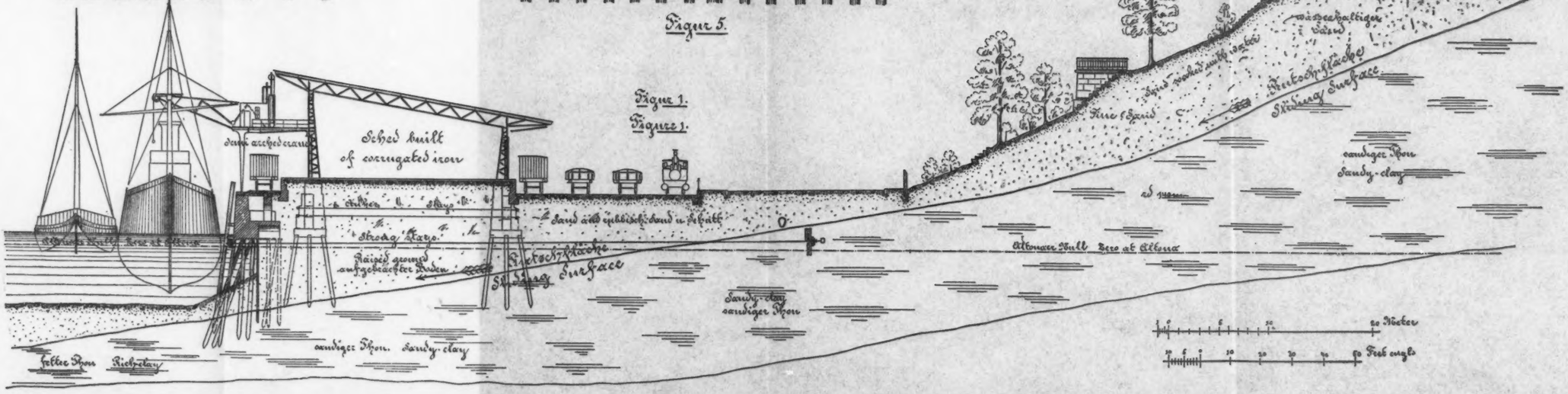
Figur 2.







Figur 5.



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647.

(Vol. XXX.—November, 1893.)

EXPERIENCES HAD DURING THE LAST TWENTY-FIVE YEARS WITH WATER WORKS HAVING AN UNDERGROUND SOURCE OF SUPPLY.

By B. SALBACH, Baurath at Dresden, Saxony, Germany.

Translated from the German by CLEMENS HERSCHEL, M. Am. Soc. C. E.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

The preconceived opinions which are frequently expressed against underground sources of water supply have induced the author to publish the result of his experience gathered during 26 years of practice, devoted almost exclusively to this branch of engineering. Although this paper will consist merely of a series of descriptions of water works of this kind, the attempt will, nevertheless, be made to explain the underlying principles of such works, and it is to be hoped that other gentlemen, active in the same branch of engineering, will add the results of their experience.

An examination of the statistics of water works constructed in recent times will show that the number of such works having under-

NOTE.—Discussions on all papers presented to the International Engineering Congress will be published simultaneously in the number for December, 1893.

ground sources of supply has increased in greater proportion than those drawing from rivers and filtering the water thus drawn; and the use of such sources is destined to attain a still greater increase, by reason of methods, which have been discovered quite recently, for changing to a good quality water which, when first drawn, does not seem fit for use. Water of this kind, when drawn from a considerable depth, even when requiring such treatment, offers the best of assurances that it does not contain the germs of destructive epidemics.

Although the experience of the year 1892, in Hamburg and Altona, has shown that a proper filtration of water is accompanied by the best of results in this respect, the assurance is, nevertheless, not present, as was shown in 1893 at the filtering plant of the Insane Asylum at Nietleben, near Halle, that a water containing disease germs will be deprived of them under all circumstances, and that accidental defects in the operation of the filters will not become a source of danger to health. It must also be admitted that a great danger is at hand in the use of underground water, when the wells cannot be kept free from the effects of sewage sinking into the ground, and care must be taken to prevent injury of this kind. It does not, however, argue against such water in general that certain wells have been dug in improper places, and that epidemics have been caused through the infiltration of sewage; it is also an unauthorized assertion, though often made, that the future yield of underground sources of water supply is necessarily a matter of great doubt.

The following descriptions of underground supplies which have proved themselves to be good throughout a long series of years should remove a prejudice of this kind, and, though expectations have not been met in certain places, continuous experience has shown the reason therefor, so that experienced specialists may, in all cases, judge of the existing circumstances with sufficient certainty. In these examples special attention has been given to the development of, and the experience had with, the works of the city of Dresden during 18 years of operation, because especially important points may be illustrated in describing this case, the understanding of which will enable every reader to reach a proper conclusion.

The author was called, in the year 1867, by the city government of Halle to report upon the preliminary works then under way for testing the sources of supply, and upon a project for the water supply of the

city. These works consisted of borings in the Aue, near Beesen, above the junction of the Elster and the Saale, which had penetrated a thick and widely extended bed of gravel, and in drawing for a long time large quantities of water from a well which a chemical analysis had shown to be fit for the proposed supply.

It had been assumed, before undertaking the examinations, that the water had penetrated this bed of gravel from the neighboring rivers, and that when removed the river water would replace it after a natural lateral filtration of the same through the banks. That this assumption was erroneous was speedily shown after a short operation of the pumps at the water works. In the first place, the water taken from the gravel was shown to have an entirely different chemical constituency from that of the river water, and it was shown, furthermore, by a series of experiments that a natural filtration of the river water was wholly impossible.

To prove this, several wells were dug along the shore of the river, in which the ground water maintained a level of about 4 ft. lower than the river water, following a suitable operation of the pumps. When this was the case, the earth over the whole water level on the river side was entirely dry; extending the well laterally until within about 14 ins. of the bank of the river would cause no flow of water from the bed of the river into the well, and this last 14 ins. of soil was dense and impervious to water. These examinations proved that, in this case at least, there was no flow of water into the bed of gravel of the valley from the river, and that the water drawn from the wells was an independent underground source of supply which flowed parallel to the river through the gravel and followed the general slope of the valley.

The opinion expressed at the time was quite general that this bed of gravel constituted an independent basin, which would be exhausted after a certain amount of pumping; but this was disproved by the fact that after pumping a long time, the water in the wells very quickly regained its original level. There was then great difference of opinion and much fear regarding things which have now, after an interval of 26 years, become well known to all experts in this branch of water supply. Nevertheless, the fundamental principles of well-water supply have been established by the experience of the water works of Halle. These works now supply six times the quantity they were originally built to supply, due to the growth of the city and the draft of a large

number of factories which have been erected since that time. The construction of all the larger well-water supplies for cities in Germany has been based upon the experience of Halle.

An examination of the water derived from the gravel showed that it was harder than the water of the adjoining river, while that of the Saale was still harder than the water of the Elster gravel. The water of the Elster gravel was shown, shortly after the pumps were started, to contain considerable iron and to be disposed to breed algæ, which circumstance caused the abandonment of the wells situated in it. Since that time, the Halle works have yielded an unexceptionable well water, up to the amount, in the year 1882, of about 3 750 000 galls. per day (12 840 cu. m. per day).

In passing, the author desires to refer to an attempt, which was made in 1868 at Halle, to purify the water containing iron, and which has quite recently again been used.

It consisted in allowing the water to flow from the main pipe upon a box of gravel, having a sieve at the bottom, and a sand filter beneath it, and in this way it was favorably exposed to the action of the air. The result was a quick oxidation, as well as an escape of the sulphureted hydrogen, and a yield of perfectly clear and beautiful water. This process was adopted at a later date by the management of the Charlottenburg water works, at which place the same evils were encountered, and, subsequently, was improved upon; and ferruginous water of these works, found in certain of the wells near the Devil's Lake, was thereby made of a desirable character.

This process may properly be used in many other places at which the supply of well water has had to be abandoned on account of the amount of iron held in solution; it will be the more serviceable in such cases, because, in most instances, water of this character, so soon as freed from its iron compounds, has been shown to be of unexceptionable quality. Frequently, a mere aeration will cause the heavy iron compounds to be precipitated, and will suffice; as, for example, in the case of the water works supplying Norderney, a watering place on the North Sea. The water which is taken from wells dug in the sand of the island is unfit for use, whether for drinking or for other domestic uses, on account of the quantity of iron held in solution. It is aerated in a tower, in which is a stand-pipe, and, from this, passes to a closed reservoir, in which the iron is precipitated sufficiently during the

slow movement of the water, and is fit for the domestic supply of the island immediately upon leaving the reservoir.

Water containing iron is found in large quantities in the subsoil of the whole North German plain; in Holstein, Schleswig, Friesland, in the eastern part of Prussia, and in Holland, and has hitherto been considered entirely worthless. This water will soon, no doubt, be made use of in the manner described, because, by reason of its being drawn from a considerable depth, it offers the best of assurances of being entirely free from contamination in any form, while a filtration of river water does not offer absolute assurances that such water, when once charged with bacteria, will, under all circumstances, again be cleared of them. Shortly after the completion of the Halle water works, the city of Berlin directed Civil Engineer Veit Meyer to make examinations for a supply of well water from the vicinity of that city. Such examinations were made near the Tegel and the Müggel Lakes, and showed very favorable results, so far as quantity was concerned. But the water drawn from these wells presented the same phenomena as that drawn from the Elster gravel, so that they were not used. Similar phenomena were also observed at other places; as, for example, at Nürnberg, Leipzig, Königsberg in Prussia, and at certain wells of the Charlottenburg water works, as above mentioned.

This quality of the well water of the Weser valley was exhibited in a striking manner in the experiments conducted at Bremen in 1869. A gallery constructed in the vicinity of the Weser, for purposes of preliminary examination, yielded very considerable quantities of water. This, when drawn from the wells, was perfectly clear; but in a very short time became of a brown color, and, after a short period of settling, precipitated a considerable amount of clayey iron oxide, leaving the water above it perfectly clear.

The results found at the water works built by the author for the city of Groningen, in Holland, will be of general interest. Although they do not strictly belong here, it is the author's wish to publish them for what merit there may be in them. These works have their source of supply in a river, called the Drentsche Aa, and water is delivered to the city after settling and a sand filtration.

After heavy rain storms, and during spring freshets in the river, the water is colored brown by turf bogs situated further up stream and retains its yellowish, brownish color after filtration, although other-

wise clear. To remove this color, a small quantity of alum* is added to it by a small pump, while on its way to the settling basins. This addition of a saturated solution of alum amounts to about 1 to 10 000, or 1 to 20 000, of water. In the settling basins the alum is speedily distributed throughout the mass of water and greatly aids its clarification. The coloring matter contained in the water, principally iron, is precipitated, and the water after settling from 12 to 14 hours, and being filtered, becomes entirely clear and without color. A chemical examination of the filtered water shows that the alum disappears from the water after clarification, and that the sulphuric acid contained in the water is increased by a minute and hardly perceptible amount. A very important result was proved by the experiments of Professor Dr. von Calcar, of Groningen, viz., that during this operation, every trace of bacterial life had vanished.

The alum which is gathered in the residue of the settling basins retains its action for some time, so that the amount of alum to be added can be diminished. The sludge removed from the settling basins forms a valuable manure. The cost of this operation is very small, in view of the use to which the sludge can be put, and it is of material benefit to clarify the water and free it of iron compounds, and to destroy deleterious germs contained in the water. The system has been tried at this place for 13 years and may, in other like cases, be of great service.

In certain cases, when there is only a small amount of iron in the water, as, for example, at the new water works of the city of Leipzig, it has been left for consumers to remove the same by individual filters; but this cannot be recommended, as it is difficult to control the cleanliness of such filters, and it would be better that the treatment and clarification of the water should take place before it is allowed to enter the distribution pipes.

To deliver water in such large quantities as 10 000 000 to 25 000 000 galls. (40 000 to 100 000 cu. m.) per day, and of such quality as hygiene demands, and, generally, to satisfy the requirements made in recent years upon a public water supply of large cities, is a matter fraught with many difficulties, the more so when it is required that all the water delivered to consumers, whether used for drinking or other household

* Experiments with an injection of a small quantity of chalk produced approximately the same result; but the water in that case was made to have a disagreeable taste.

purposes, or for the watering of streets and gardens, is to be of unexceptionable purity. Such requirements are more easily complied with in the case of small cities; but are, even then, difficult of attainment.

The opinion is often expressed that cities should avoid no expense to supply themselves with water from mountain springs. In discussing the water supply of Hamburg, assumed to have been the vehicle of the cholera epidemic of the year 1892, it was suggested that the city should get a supply from the Harz Mountains, and, previous to this, it had been suggested to supply the city of Berlin from the same source. The author has attempted, during the course of many years, to find enough spring water to supply the smaller cities situated along the foot-hills of the Harz Mountains, but has failed almost completely, and it is now in contemplation to supply these cities by means of artificial storage reservoirs.

Examinations have shown that the Harz Mountains contain but very little spring or well water, so that any plan to supply larger cities from such a source must be based upon total ignorance of the circumstances of the case. There are no extensive drift valleys reaching out into the plain below and constituting the real collectors or reservoirs of ground water, which, flowing off the mountain ridge, enters these drift deposits and pursues its way to the valleys and plains by underground courses. The decomposed granite and slate of the mountain ridge have made the drift foot-hills stanch and almost impervious to water, so that the water, not being able to sink into the ground, runs off on the surface. The foot-hills which consist, for the greater part, of chalk débris, and which dip upwards to the mountain range, yield a water so hard that it is not fit for purposes of a domestic water supply. Similar conditions obtain in the Thüringer Forest, although we find here a greater amount of drift valleys and of deposits of this material in the river valleys, which have their rise in this mountain range.

More copious spring-water formations may be found in the Riesengebirge, in the Eiffel, in the Carpathian Mountains and especially in the Alps. Without exception, we there find, adjoining the mountain range, great valleys of drift formation, which may be followed down into the plain, and in which the water, falling on the mountain range, is mixed with the rain water penetrating the soil of

the valleys and flows as an independent spring-water stream until these gravel and drift formations reach the bottom of the sea. The volume of these subterranean streams may be seen from various phenomena. For example, in the North Sea, in the vicinity of the islands surrounding Holland, there are springs which may be recognized in the water of the ocean, 2 or 3 miles from the shore, and from which fresh water may be drawn apparently from out of the ocean. Similar springs may be found in the Adriatic Sea, near Fiume, Abazzia, Triest, and in other places where the rain water penetrates into the ground in the Karst Mountains, appearing again in the sea, so that at these places the surface of the sea is slightly raised up, and a whirlpool may be observed.

As a surface stream is formed by an immense number of smaller independent contributary streams, and thus gradually becomes a mighty river, in like manner subterranean water-courses are formed from similar subterranean streams. These, gathered together in adjoining pervious sand and gravel beds, form larger streams, which flow along impervious inclined layers, situated beneath those which carry the spring water.

In the plains there are often found a series of strata saturated with water, which are separated by other great strata of clay, on penetrating one of which the water, which is under pressure in the gravel beneath, will rise to the surface and form a spring.

In certain valleys the ground water, flowing along beneath the surface, rises to such a height that it threatens to convert the surface of the ground into a swamp, which can only be prevented by affording a channel in the shape of deep ditches for the flowing off of the spring water. Such artificial springs often yield a very large quantity of water, and indicate localities where still greater amounts may possibly be gathered.

But subterranean streams are fed, not only from the mountain ridges, but at all points where the soil is pervious between them and the surface. Rain falling upon such a surface penetrates the ground in a vertical direction, so long as it does not meet with impervious strata, and adds to the flow of the subterranean streams. The rain water thus penetrating the ground takes up carbonic acid from vegetation and from the surface loam and dissolves with its aid a portion of the minerals found on its way. The more such sub-

stances taken up by the water, the less useful it is for a domestic water supply. If lime be the impurity, hardness results; if salts of iron, the water when exposed to the oxygen of the air, at a later stage, will show the phenomena previously described in this paper; or if the water be vitiated by local deleterious matter, it will have become unfit for purposes of a domestic supply.

To find such subterranean contiguous strata saturated with spring water, and to open them up at proper places, at the same time seeking to know the direction of their flow, their extent and their velocity, constitutes the basis of a successful spring-water supply. Failure has often resulted from lack of sufficient preliminary examination, which has then been the occasion for opponents of this system to represent such water supplies as of dubious value. In giving examples of such works the author desires to say that he distinguishes between cases where water supply works have been wrongly planned and those other cases where the works were at first sufficient for the then requirements and had to be extended on account of the increase of water consumption. In the latter case, it has often been maintained that spring-water supplies can be successful only for a certain length of time, and that a diminution of their yield can only be prevented by continually extending the works.

It has, to be sure, happened that certain works have yielded less water, after being in use for some time, than had originally been assumed. They had to be extended until the demand upon them had been brought into balance with the natural yield of spring water. The yield depends, of course, upon the amount of rainfall, so that considerable fluctuation in the elevation of the ground water may occur, which in certain cases had not been guarded against. Nevertheless, proper preliminary examinations will determine with great certainty what amounts of water may be drawn from wells, even after periods of the greatest drought, and forethought must be taken in such examinations as to the direction in which further extensions may, when necessary, be made. It must also be remembered that the engineer has not always at his command a sufficient appropriation to build works of sufficient capacity to last for all time, and that he can do no more than to provide, to begin with, as to the manner of making extensions.

One of the first spring-water water works in Germany was that of the city of Leipzig. An attempt was made in that case to get the

water for a domestic water supply from two wells of large diameter, which were situated in the valley of the Pleisse, near the shore of the river. Whether at the time it was intended to draw from an independent supply of ground water, or whether a natural filtration of the water of the river was planned, was probably not settled at the time; but the water from these two wells was ground water, and contained a great deal of iron, so that complaints of the consumers speedily followed. Upon this, some of the river water was mixed with the well water. This diminished the proportion of iron in the water. At a later day, collecting galleries were built on the shore, also artificial filters, and through many years the water of the Leipzig water works left much to be desired with respect to its quality and quantity.

Only a few years ago a subterranean stream of water was found in the vicinity of Grimma, near Naunhof, in an old, abandoned channel of the Mulde which, since that time, has supplied Leipzig with an abundant supply of water.

The water works of the city of Bernburg were built in the year 1876. The source of supply consists of a row of wells in the valley of the Saale, which were originally built to supply 625 000 galls. (2 500 cu. m.), per 24 hours for a population of 16 000. It was then extended, as the population had increased to 34 000, on January 1st, 1893, to a capacity of 1 000 000 galls. (4 000 cu. m.) per 24 hours. Until a short time ago, these works yielded an unexceptionable water which remained absolutely clear and pure, even during the time of freshets in the Saale, although the plain in which the wells were dug is overflowed at such times. The variation of temperature was only $\frac{1}{2}^{\circ}$ in the course of the year, not being affected, at the distance the wells were from the river shore, by the warmer river water.

From the result of tests made for the water works for the city of Halle the assumption was justified that this was a case of independent subterranean ground water; but this assumption was disputed when the water from the Bernburg wells similarly with that of the Saale was found to contain salt to a considerable extent. The salt in the Saale has its origin in the discharge from the Mansfeld mines, which is allowed to flow into the river, and it has increased in the course of time to such an extent that the waters of the Saale are, for other purposes, useless. Some 1 750 000 lbs. (82 000 kg.) of salt, are thrown

into the Saale every day, and in low water of the year 1892, the Saale was nearly brine.

Although the water drawn from the wells of the Bernburg works, as well as that drawn from other wells in the valley of the Saale, contains, by no means, the quantity of brine that may be found in the river itself, yet it contains enough to render it unfit for drinking and for such culinary purposes as do not call for the addition of salt.

The city of Bernburg, which hitherto has taken a great deal of pride in its water works, was put in an unpleasant position, being compelled to seek a new water supply, which it is intended to bring to the city from a distance of 5 miles. For this purpose a well has been dug in an extensive bed of gravel, situated between Stassfurt, Rathmannsdorf, Güsten and Ilberstedt. This gravel is from 30 to 40 ft. thick and rests upon an impervious stratum of red clay. The plain has an area of about 200 sq. miles and allows a great mass of rain water to penetrate into it. The water gathers on the impervious red clay and flows, following the inclination of the stratum, towards the valley of the Wipper and the Bode, which are about 3 miles from the well.

This well yielded about 1 500 000 galls. (6 000 cu. m.) in 24 hours, and the yield was shown to be capable of still greater increase. If it were argued that the water of the Bernburg water works had been mixed with a portion of the salt contained in the water of the Saale, on account of natural and only partial filtration of the Saale water, it would have to be admitted that so much of the water of these works as does not come from an independent ground water supply had been successfully filtered for 16 years. But it must be considered that frequent freshets in the Saale had allowed much salt water to penetrate the surrounding soil through which the subterranean water flowed; also, that salt will penetrate layers of earth; as, for example, clay or muddy soil, through which clean water will not flow to any material extent.

The reason for the location in valleys of water works depending on a supply from wells is generally to be found in the situation of gravel and shingle deposits, which, reaching down from the mountain ridges to the valleys and carrying off spring water, are exposed to a greater extent, in the deep cuts formed by the river valleys than elsewhere. The

greater part of these depressions was formed by movements upon the earth's surface a long time before the existence of rivers as they now are, and the deposits of gravel and shingle referred to are of much more ancient origin than the rivers themselves, which latter are generally excavated in more recent formations. Especially interesting examples in this regard are the sources of supply of the water works in the valley of the Rhine, of Bonn, Cologne, Elberfeld, Düsseldorf, Mannheim, and also of the city of Dresden, which will be described more in detail.

In Bonn, water is taken from wells in the vicinity of the Rhine, which yield considerably harder water than that of the Rhine, the former being of exactly the same constituency as the spring water found at a considerable distance from the Rhine.

The chemical analyses made regularly, several times in the course of a year, of the water furnished by the Cologne water works, are exceedingly instructive. As the consumption increases, the level of the water in the well varies with it, being more or less depressed, according to the amount pumped. Chemical analysis shows a softer water the greater the amount pumped. As the works were extended by the construction of new wells, the water became harder until an increase in the amount pumped, upon which it became softer again, and again steadily became harder when new wells were constructed.

This process may easily be explained. As the consumption increased and more water was drawn from the wells than had originally been contemplated, the level of the water was lowered more than usual. Excessive depression of the level of the water in the wells would cause the water from the river to enter the wells, and, by mingling with the independent ground water supply, would make it softer. The construction of new wells would raise the level of the ground water in all of them; the curved surface of the water table, feeding the wells, would no longer intersect the water level of the river, and the result would be a harder well water, until a further increase of consumption would again cause the river water to flow in, and would again result in the wells yielding softer water. Of course, each case must be judged by itself, to determine what level of the water in the well will cause the river water to flow into it, and what level may be depended upon to furnish only spring water, dependent upon the form and extent of the geological formation.

Examples of the yield of large quantities of spring water for many years will counteract the often-expressed prejudice that all such works yield nothing but filtered river water, especially as the votaries of this opinion generally deny the possibility of a natural filtration of river water. The direction of a current of spring water into wells must primarily be considered, in order to get a clear idea of how the wells are fed. The water works of the city of Munich furnished an interesting example of well-water supply. The subsoil of the Bavarian plain, situated to the north of the Alps, consists of a deposit of débris of great depth emanating from the limestone of the foot-hills. Below the foot-hills there are valleys of this débris which adjoin the subsoil of the plain, consisting of gravel and shingle. The strata of the latter have between them an impervious bed of tertiary blue clay of considerable thickness, the surface of which is corrugated and crossed with valleys.

Rain water falling on the mountains, as the surface is very porous, penetrates into this débris and into the gravel beds over the blue clay, and, following the latter, flows through the subsoil until it appears on the surface at certain points, or is forced to run into the river, or into brooks, some of which disappear into the ground after reaching the soil of the Bavarian plain. During the course of the examination made by the author for the supply of the city of Munich, during 1874 and 1875, many such disappearances were discovered, as, for example, the disappearance of the Kirch pond in the vicinity of Holzkirchen, near Mangfall valley, which is fed by the rainfall of the surrounding foot-hills, and whose outflow at one time gauged 18 750 000 galls. (75 000 cu. m.) in 24 hours, but which wholly disappears after flowing about 1 mile in the brook called Hell's Ditch.

As the surface of the impervious layer of clay is corrugated, as has above been noted, large quantities of spring water enter the valleys from the side hills, where the clay has thus been exposed by the cutting action of the streams, sufficiently large, in some cases, to run several mills. It is one of these springs, on the left side of the Mangfall valley, near the village of Darching, which supplies the city of Munich. The water, thus found, is of very good quality—not being too hard—for the domestic supply of the city.

The spring water in the valley of the Inn is much harder than that of the Mangfall valley, and is not fit for a domestic water supply

although large in quantity. That of the valley of the Traun, near Scharlinz, for the supply of the city of Linz, is of excellent quality and of unusual volume.

Not only in the Bavarian Alps may these deposits of débris and and gravel be found, but the whole valley of the Danube, down to the Iron Gate, has been thus filled to a great width and thickness, and the beds join similar ones from the mountains. The water works of the city of Pressburg furnish at all times an unexceptionable supply of spring-water from the deep well which is situated on an island in the Danube, up stream from the city. By lowering the level of this well about 4 ft., the well was caused to yield about 2 500 000 galls. (10 000 cu. m.) in 24 hours. Experiments made by the author in 1890 on the left bank of the Danube, above Buda-Pesth, demonstrated an unlimited yield of well water of the best quality to be had from the gravel of the Danube valley. The yield of each of three experimental wells, by lowering the water level about 10 ft., was from 3 000 000 to 3 500 000 galls. (12 000 to 14 000 cu. m.) in 24 hours, at which yield the water table gently rose from the level of the water in the well to the banks of the river, and it was concluded that a supply of 50 000 000 galls. (200 000 cu. m.) in 24 hours could be drawn from the property of the city. The construction of new water works from this source of supply has since been determined upon. One of these wells, situated about 1¼ miles from the river and yielding about 3 500 000 galls. (14 000 cu. m.) per 24 hours, furnished water of an especially good quality, according to chemical and bacteriological analysis. Mixing with it some water containing iron taken from the left bank of the valley, after standing for some time it became slightly cloudy; this was caused by the effect of the oxygen of the atmosphere and the low form of oxidation of the iron contained in the water. The attempt to mix this water before it had been exposed any length of time to the air, in equal parts with water taken from one of the other wells, resulted in no trace of cloudiness, because the iron salts were no longer present in sufficient quantity to be affected by the oxygen of the air.

Similar results, as regards the subterranean flow of water, were found during the construction of the water works in Mahrisch-Schönberg, in the valley of the Theiss, and at Olmütz, in the valley of the March; but, in the latter case, the river-bed was found to consist, for a depth of from 26 to 33 ft., down to the underlying blue clay, of fine

silted sand, in which very little water of a pure quality could be found. It was necessary to go about 1¼ miles from the river, to find the water-bearing gravel bed, lying above a layer of blue clay, some 40 odd ft. below the surface. This gravel, originally coming from the Glatz Mountains, contained water of a most excellent quality, and of such volume that, in constructing the foundations for the pump-house, some 6 000 000 galls. were pumped from the pit every 24 hours in the effort to lower the ground-water level about 7 ft.

Large volumes of ground-water are found in the great masses of gravel filling the subterranean valley of the Ruhr, and a number of water works, as, for example, those of the cities of Dortmund, Mühlheim, Oberhausen, Barmen, etc., and the very extensive water works of Krupp's Steel Works, have been using this water for many years. It differs materially, both in quality and clearness, from the water of the Ruhr itself.

The water works of the city of Cöthen are 7½ miles from the nearest water-courses—the Mulde and the Saale. During the preliminary works conducted by the author in the year 1887, beds of water-bearing gravel, 26 to 33 ft. thick, were found in the vicinity, lying above a stratum of blue clay and under a thick upper covering of clay. The examinations showed that the surface of the blue clay had in it several deep grooves which apparently converged toward the Peter Mountains. These grooves contain the water-bearing gravel beds, and a well dug in one of them yielded 1 500 000 galls. in 24 hours of the purest and most serviceable water for domestic supply. When yielding this amount, the capacity of the well was not reached, as a depth of about 20 ft. of water still remained in it.

Attempts to get well water in the valley of the Theiss and Maross, and throughout the valley of the Oder, have failed. In these valleys, nothing but fine silty sand and clay were met with, and, besides, the little water found in the upper Oder valley, in Austrian Silesia, was strongly impregnated with iron.

Further examples of successful wells may be found in the water works built by the author in the years 1875 and 1876 for the city of Crefeld. The occasion for building these works was found, not only in the limited supply of the wells of the city, but also in the poor quality of the water, which had been vitiated by the infiltration of sewage from adjoining buildings. The supply was sought in a region

of country not yet affected by sewage. In doing this, it was necessary to determine the direction in which the subterranean water-courses were flowing, so that the new source of supply could be placed up stream from the city as regards these underground currents.

The tract of land contemplated was situated some 6 miles from the Rhine, and proved to consist of a bed of water-bearing gravel about 36 ft. thick under a top layer of clay, from 3 to 6 ft. thick; under the gravel, a stratum of clay some 6 ft. thick and then another bed of gravel which was explored to a depth of 90 ft. Borings were not continued at the time; but later borings in the vicinity of the works showed blue clay at a depth of 116 ft., rising towards the Rhine, and appearing in its bed in some places. This stratum of clay forms a deep channel in which flow underground streams of water of great volume. In the preliminary examinations, samples of water were taken, both from the upper and lower beds of gravel above referred to. Chemical analysis showed a small percentage of iron in the water of the lower gravel bed; but, nevertheless, the water of both gravel beds was declared to be of a good and wholesome quality.

The works constructed on the basis of this opinion, and on the quantitative experiments, yielded a very fine water. They were built of a capacity of 2 000 000 galls. per day, with the expectation of increasing this quantity in the future by deep wells to be bored into the débris lying under the bed of gravel.

After 10 years' service, the city of Crefeld having grown very largely, and the consumption having increased to 1 500 000 galls. in 24 hours, these deep wells were put down. It appeared, however, that the water lost materially in quality, on account of the iron contained in the water taken from the deep wells, and these were accordingly again closed. In the meantime, on account of the sewerage works of the city of Crefeld, and especially on account of the deep sewage channel leading to the Rhine, which had given the ground water of the vicinity ready means for flowing off, and had lowered the water-table in the vicinity of the city by about 4 ft., the upper gravel bed no longer yielded so much as 1 500 000 galls. per 24 hours.

Inasmuch as it was expected that the consumption of water would soon demand a larger capacity, renewed experimental borings were undertaken in the direction of Gladbach, which resulted in the discovery at this place of a bed of gravel 116 ft. thick, without any inter-

vening clay. A well sunk to a depth of 116 ft., and taking water only at this depth, yielded water of good quality, but it contained the same quantity of iron as did the water of the deep wells of the existing water works. Continued experiments led to the result that at this place water free from iron could be found at a depth of from 60 to 66 ft., and this result was confirmed by putting down two wells to a depth of 60 ft. on the same piece of property, which have yielded for years an unexceptionable quality of water in abundant quantity, so that these works supplied, in the year 1892, up to 3 750 000 galls. per 24 hours. In the meantime the author built a second water-works plant in Crefeld, of a capacity of 7 500 000 galls., and the last two years have shown that from the nine wells of these works water of sufficient quantity and of proper quality can be drawn at all times.

Artesian wells in Silesia, at Breslau, Oppeln, Laband, Peiskretscham, Gleiwitz, etc., have been bored with considerable success. The author had charge, for example, in the year 1875, under orders of the Royal German Government, of the borings of artesian wells near Zawada, in Upper Silesia, in which sandstone was struck at a depth of about 500 ft., under a thick bed of chalk, and which yielded, by means of pumping, water of very good quality up to about 4 500 000 galls. in 24 hours. The project of supplying water from these wells to the Upper Silesian manufactories not having received further attention, the drought of the year 1892 forced a consideration of such a supply. Gaugings taken in 1892 showed a yield of about 3 000 000 galls. in 24 hours. But it is to be assumed that during the course of 17 years the lower portions of the pipe have gradually silted up, and that a redrilling and cleaning of the bore hole will restore the former yield. It was formerly projected to drill a well of still larger diameter, in which the level of the water could be lowered by pumping, and thus cause a still greater yield. From experiments made by drawing the water down, and noting the yield at different depressions of the water in the well, it was at the time determined that by lowering the water-table 20 ft. this well would have a yield of 8 250 000 galls. per 24 hours.

The water works of the city of Dresden were designed and built in the years from 1873 to 1875, of a capacity of 7 500 000 galls. (30 000 cu. m.) per 24 hours. In the meantime they have not only yielded the desired quantity and quality of water, but have gone beyond it. The

maximum daily consumption during the last 11 years has been as follows:

Year.	Month and Day.	Million Gallons.	Cubic Meters.
1882.....	July 20th	6 669 000	26 676
1883	" 5th	7 342 000	29 368
1884.....	" 17th	7 047 000	28 188
1885.....	" 27th	7 848 000	31 392
1886.....	May 22d	7 730 000	30 920
1887.....	July 30th	8 708 000	34 832
1888.....	June 25th	8 836 000	35 344
1889.....	" 8th	9 230 000	36 920
1890.....	May 24th	8 762 000	35 048
1891.....	Aug. 29th	8 506 000	34 024
1892.....	" 20th	10 561 000	42 244

The analysis of a sample of water taken from the distribution pipes, made by the Government Chemical Laboratory, on August 12th, 1891, being at a time of maximum consumption, gave the following result in 1 liter of water (1 000 gr.):

Grams.	Substances.
0.1569.....	Solids held in solution in which were contained:
0.0020.....	Organic substances.
0.0113.....	Chlorine.
0.0096.....	Nitric acid.
0.0422.....	Chalk.
0.0124.....	Magnesia.
0.0000.....	No trace of the nitrous.
0.0000.....	No trace of ammonia.
5.96.....	German degrees of hardness.

Professor Dr. Neelsen reports as follows upon the bacteriological examination of the water, made in the year 1892.

"In accordance with a request made on September 15th of the present year, the undersigned, in conjunction with City District Physician Dr. Niedner, and Government Engineer Krumhaar, took samples of water at the places named below, on October 8th, in the afternoon, between 3 and 6 o'clock. The samples were gathered in sterilized glass jars, and the bacteriological examinations were commenced the same evening by pouring some of the samples upon gela-

tine plates. Of each sample, three plates were prepared with ½ cu. cm. of water each. The number of developed germs on these plates was determined after 36 to 60 hours, and, from the average number found, the round number of germs in each sample per cubic centimeter was determined. At the same time, the number of species of bacteria on each plate was determined by inspection, as far as possible. (An accurate count would have taken a good deal of time, and would have been of no material advantage.) Finally, the several species were propagated on gelatine, in order to determine their identity with known forms of bacteria.

"The result was as follows, for the several samples taken:

"I.—Water of the City Distribution Pipes.

"(1) Water taken from the well at the pump house contained from 70 to 80 healthy germs per cubic centimeter. In determining the species, it was shown that approximately half of all the colonies that had been developed were formed by *Micrococcus aquatilis* (a circumstance which was repeated with all the water samples, and, therefore, need not be mentioned again each time). About one-third of all the colonies were composed of two organisms, in about equal number, viz., *Micrococcus flavus desidens* and the *Bacillus fluorescens simplex*. The remainer, about one-sixth, was chiefly composed of colonies similar to a species of yeast, which slowly dissolved the gelatine, and of the *Bacillus fluorescens liquefaciens*, as well as of a few colonies of the *Bacillus subtilis*.

"(2) The Fischhauser Revier basin contained 80 to 90 germs to the cubic centimeter, and of the same sort as the well, and also in approximately the same proportion as to numbers. The increase in the number of germs may be explained by the circumstance that in this case about the same amount of the *Bacillus liquefaciens simplex* was found, in addition to the above-named *Bacillus fluorescens liquefaciens*. No specimens of *Bacillus subtilis* were found in this sample.

"(3) The same favorable condition as regards the absolute number of germs, as well as regards the species found in the case of the two above examinations, was maintained in the bacteriological examination of the further five samples taken from the whole distribution system.

"Although the number of germs was somewhat larger than in the well and in the collecting basin, there was only a slight increase. In the kitchen faucet of the dwelling house of No. 33 Wincklemann Street, there were about 100 per cubic centimeter; approximately, the same number in the stand-pipe at the Bohemian Railway Station; in the kitchen faucet of the dwellings No. 72 Bautzner Street, second story, and No. 20 Blochmann Street, third floor, 100 to 120; there were from 120 to 150 in the faucet of the microscopic laboratory of the City Hospital. The number of species present remained almost the same. In three samples (Wincklemann Street, Bautzner Street and the City

Hospital) single colonies of *Bacillus aquatilis sulvatus*, and of *Bacillus liquidus* were found, besides the species already named, and these were probably not found in the well and in the basin by accident, because they are usually met with in all water. Detached colonies of *Micrococcus candicous*, of yellow sarvine, and of little brown *cocci*, could be discerned, though probably they came from the air.

"The increase in the number of bacteria in the water taken from the distribution pipes does not indicate a growth of the germs in the pipe. The growth of the germs takes place on the damp walls of the faucets, on which the bacteria find favorable conditions of development when in contact with the air. This is shown by the disproportionate increase of the species which thrive upon exposure to the air; that is to say, of the *Bacillus liquefaciens* and the *Bacillus fluorescens liquefaciens*. Colonies of this kind are found in greater numbers, and, in this way, contribute to the increase of the total number of germs found, the number of other germs showing no increase.

"The effect of the orifice of efflux, especially when its interior surface had not been cleaned for a long time, was clearly shown in the case of the stand-pipe of the Bohemian Railway depot. At the preliminary examination on September 20th, it was found that a number of germs at this stand-pipe were twice as great as in the kitchen faucet of the dwelling house No. 1 Stall Street, on the ground floor, the number of germs in which agreed perfectly with those found in the kitchen faucet of the other houses. After cleaning the stand-pipe at the depot in a thorough manner, the sample taken on October 8th gave the result above noted, agreeing with the number of germs taken from the other faucets.

"Inasmuch as all the bacteria found in the water taken from the distribution pipes are known to be wholly harmless, and as the number of species and the total number of germs found is a very small one, the water may be declared to be an especially good one, and responding to all the demands of hygiene to be put to it from a bacteriological standpoint."

Although the maximum consumption above given was used as a basis for the construction of the works, it has been exceeded daily, and the demand has been met by the works without difficulty; the question had, nevertheless, to be considered what steps to take to prepare for an extension of the works, in view of the probable great increase in the number of inhabitants to be supplied because of the annexation of certain suburbs.

At the time the works were constructed the city of Dresden had 177 500 inhabitants, which had increased by January 1st, 1893, to 305 144. In view of this increase, the city government has undertaken,

in the course of the last few years, under direction of the builder of the works, a series of examinations, to determine the amount the existing works could possibly supply, and what measures should be taken, to enable them to satisfy a still further increase of consumption. These examinations showed that the existing source of supply could be depended upon to supply 15 000 000 galls. in 24 hours, on condition that the water level in the collecting well, into which the horizontal collecting galleries empty, is lowered deeper than had originally been intended, or had, up to the present time, been necessary. The existing pumping capacity was, however, only 11 250 000 to 12 500 000 galls. in 24 hours. This capacity would, therefore, have had to be increased to 15 000 000 galls. in 24 hours. On the advice of the author, the city government did not adopt this method of extension, as he had shown that an inordinate lowering of the water-table, for the purpose of getting materially larger quantities of water, would probably interfere with the yield of the independent ground-water supply; that the extension of the water-table to a greater distance would cause it to intersect the surface of the neighboring river, and would thus produce a head, or water pressure, which would cause a flow of the water of the Elbe into the subsoil of the river-bed.

In proof of this, the author presented at a meeting of the city government a report of the examinations that had been made up to that time, and added to it the result of observations during the 18 years of operation of the works, which are here given in abstract. The preliminary examination for the construction of the existing works commenced with the examination of the geological situation, aided by the valuable experience of Professor Dr. Geinitz, of Dresden. Further, by a series of borings at the side of the river bank, the level of the water-table in the valley of the Elbe, the formation of the ground in the water-bearing upper subterranean layers and the general constituency of the samples of water taken from the different bore holes, could be determined. The several bore holes put down on the right bank of the Elbe showed a steep slope of the water-table at right angles to the river. The examination of the ground-water taken from these bore holes showed it to be exceedingly pure, and of an appreciably less degree of hardness than the water of the Elbe.

Borings on the left bank of the Elbe showed a less slope of the water-table at right angles to the river. The samples of the

water taken from these borings was also very pure, but was of somewhat greater hardness than the water of the Elbe. Some borings put down in the bed of the Elbe itself, to a depth of 23 to 26 ft., showed that the ground-water in these bore holes would rise some 6 ins. above the level of the river. An examination of the samples of the water taken from these last-named bore holes showed a quality of water, which, like the samples taken on the right bank, was softer than the Elbe water, and of the same constituency as that from the bore holes first named.

The valley of the Elbe forms a wide basin between Pirna and Meissen. This basin begins up stream from Pirna at the point where the Elbe flows out from between the spurs of the sandstone mountains of Saxonian Switzerland. This valley expands to a width of several miles and is narrowed again near Meissen by the granite formations occurring at this place. Down stream from Pirna, the right and left sides of the valley forming the boundaries of this basin are composed of granite and syenite. The granite formation extends throughout the valley up to the contraction of the valley near Meissen. Further down stream the left side of the valley is formed of great layers of chalk, which extend to the vicinity of Meissen, changing to granite only about $\frac{7}{8}$ of a mile up stream from Meissen.

The geological shape of this valley is due to the granite formations on each side, in which there is at this place a deep fault. Some layers of chalk, and of sandstone and chalk, have remained on the sides of the valley, after the destruction of these more recent formations. The geological profile drawn at right angles to the valley near Dresden shows granite on the right side rising from the valley, which on the right river shore is generally met with at a depth of about 26 ft., and rises towards the plateau through the Dresden meadow, and is there covered to a large extent with great layers of fine sand. On the left side of the valley chalk is met with, superimposed upon the granite.

Under the middle of the valley, at a depth of from 50 to 53 ft. beneath the surface, a great bed of clay is found on top of the granite and on top of the chalk, having its origin in the decomposition of the chalk, and which may be considered as a lake deposit. Over the clay the whole valley is filled up with a bed of diluvial gravel mixed with sharp clean sandstone, to the thickness of about 30 ft. and becoming thinner towards the edge of the valley, in which the gathered ground-

water moves in the direction of the slope of the valley. Upon these gravel beds we find thinner beds of sand and clay, mixed with many sharp-cornered boulders of basalt, into which the river-bed has been excavated.

The layer of gravel over the clay is mixed in its lower stratum with boulders up to 800 lbs. in weight, and does not come originally from the mountain formation situated on the edge of the Dresden valley, but is composed for the greater part of basalt and porphyry from the Bohemian Mountains, and of granite from the Riesengebirge, which have been brought down by mighty currents whose course has broken into the valley of the Elbe through the sandstone mountains of the Bohemian and Saxonian Switzerland, and which have been deposited in the valley between Pirna and Meissen. The gravel and boulders found at a depth of from 20 to 50 ft. beneath the surface show by their rounded form what a great way they have traveled before being deposited; while the boulders found in the alluvial soil, in the clay and sand, consist of sandstone or basalt which have been deposited at a later period by the high water of the Elbe, and therefore present sharp, square corners.

It may, therefore, be assumed, as has also been proved by further examination in the upper part of the valley, that the whole valley consists of a channel filled with deep water-bearing layers of gravel; and that a connection may be assumed between these subterranean layers, and the layers of gravel found in the side valleys, so that the ground-water flowing on the pervious strata in these side valleys will flow from all parts into the Elbe valley, and will unite with the ground-water flowing off in this channel.

This flow of ground-water was discovered, not only during the preliminary examinations made in behalf of the water works of Dresden, but the same formation was shown to exist, by borings and wells constructed throughout this valley, at Radebeul, Ober and Nieder Loosnitz, as well as at the down-stream limit of this valley at Sornewitz and Cologne on the Elbe. At the last-named place, wells were constructed which are situated several miles from the Elbe, and which yield, by lowering the level of the water about 6 ft., from 750 000 to 1 000 000 galls. of excellent water in 24 hours.

The same phenomena may be found in the great valley of the Elbe which is situated above the entrance of the Elbe into Bohemian and

Saxonian Switzerland, at Leitmeritz, and at the junction of the Eger with the Elbe. The Elbe and the Eger flow through this valley; but the Elbe has been crowded by the inclination of the surface of the ground to the extreme right edge of the valley near Leitmeritz, where the hillsides consist of chalk formations with some veins of basalt and porphyry. For this reason the subterranean layers next the sides of the valley yield a hard water unfit for use. The chalk formations dip towards the valley of the Elbe, and the inflow from them into the Elbe, may be plainly seen during times of low water. Water found by means of borings on islands in the river at this point shows the same quality. It is necessary to go to the left shore of the Elbe and somewhat back of it, to get ground-water from the great beds of gravel of the diluvial formation flowing down stream and not yet deteriorated by admixture of hard water. Similar formations have been found in the upper valley of the Elbe, above the junction of the Moldau, near Alt-Bunzlau and Brandis.

In the lower strata of the Elbe valley at this point, great masses of débris from the Riesengebirge are found which may be recognized by their round, polished, red granite and porphyry boulders. An examination has also shown a strong underground flow of soft and very clear water from the sandstone of the Iser Mountains.

It is a remarkable phenomenon to find in almost the whole valley that the ground-water, when not changed by local lateral springs on the edges of the valley, is softer than the water of the Elbe itself. An explanation of this circumstance may be found in the fact that the most copious springs come to the valley from deep-lying and thick strata of granite, porphyry and sandstone; while the harder water, coming from higher and flatter lying strata of chalk flows into the river itself.

The sandstone formation in Bohemian and Saxonian Switzerland yields a harder water than the granite and porphyry formations, on account of the chalk contained in the limestone, because the valleys in it are cut through the upper sandstone and deep into the chalk beneath. In these deep cuts, débris of an alluvial origin has been deposited, in which the ground water coming down from Bohemia flows, and which may be found by deep borings in the Elbe itself, while the channel of the river has been excavated in the sand and clay layers above it.

After the junction of the Moldau with the Elbe, the latter receives

many large inflows of hard water from the chalk formations on the right bank as far as Leitmeritz. The contrary case has been observed in the valley of the Moldau, which, coming from a granite formation, has a very soft water. A short distance up stream from Prague, it enters a slate formation, and at this point the bed is composed of a layer of mixed granite and slate débris. An attempt to gather river water by natural filtration from wells and collecting galleries built parallel to the banks of the river failed, because the water drawn was ground-water flowing parallel to the banks of the river in the slate formation.

This hard water of the valley of the Moldau does not reach the subterranean layers of the valley of the Elbe because it is dammed up by layers of slate; but it reaches the Elbe itself by being forced to flow up into the bed of the Moldau and becoming a part of this stream. For this reason, also, the water of the Moldau, at its junction with the Elbe, is materially harder than it is near Prague.

The direction of the flow of the ground-water in the valley of the Elbe, between Pirna and Meissen, follows in general the direction of the slope of the valley; but its velocity is not uniform. The velocity of such streams may be assumed to be greater the more pervious the strata are in which they flow.

The flow takes place in the direction of greatest fall in the strata, and any increase in the amount of inflow, or greater compactness of the strata through which the flow passes, will elevate the water-table of the locality where such changes occur. An accurate examination of the strata must therefore precede any conclusions to be drawn as to the cause of a material elevation of the water-table adjoining lateral valleys. Had a conclusion been drawn from the 35 bore holes put down during the preliminary works for the second water-plant, and from the water-table found by means of these bore holes, as to what the general direction of the flow of the ground-water was, it would have led to the erroneous assumption that this portion of the flow was almost at right angles to the river.

The main current of ground-water in that portion of the Elbe valley down stream from Pirna is in a tolerably straight line, parallel to the valley of the Elbe. It takes up considerable tributaries from the granite mountains and from the Gottleuba valley near Pirna. This runs upon the right bank of the Elbe near Pillnitz and leaves it near

Übigau, crossing under the river Elbe. It flows along the granite slopes of Ober and Nieder Lossnitz, then, turning sharply towards the Elbe, enters its narrow valley near Sornewitz, where it is narrowed in between the granite Spar Mountains and the granite on the left shore of the Elbe, near Meissen. To the north, the valley and the stream of ground-water are cut off by the foot-hills near Bohnitzsch and Grobern, which are pierced by the tunnel of the Dresden and Leipzig Railway, near Niederau. In the valley between these foot-hills and the Spar Mountains a protrusion of granite makes a dam, which stops the flow of the ground-water and forces it towards the Elbe, near Sörnewitz. A short distance above this turn the preliminary works for the supply of the village of Cologne disclosed a water-bearing bed of gravel 60 ft. thick, in which the ground-water stood 4 ft. higher than in the river, less than $\frac{1}{2}$ mile distant.

The foregoing is a full explanation of the geological and ground-water situation of the valley of the Elbe, all of which was necessary to a full understanding of the underlying principles of this kind of water supply, as illustrated by the supply of the city of Dresden. In addition it was known that many sandbanks are found in the bed of the Elbe, which are moved about during freshets. The occasion of such banks is often the entering of ground-water springs which loosen the sand in the channels of rivers, so that the current may readily move it. Such points are easily recognized by the experienced eye, and may be proven by measurements of temperature, especially when there is in winter either a thin sheet of ice or no ice at all next to them.

It was natural to plan, therefore, to take only so much ground-water from the well as was contributed directly to it, and without allowing the water of the river to flow in. The extent of the springs coming from the hills down the right slope of the valley was best shown in constructing the foundations of the lower pump-house. At a depth of excavation of about 6 ft. below the water level of the river, these springs yielded, by means of several steam pumps, about 3 000-000 galls. of water in 24 hours, the water from the side of the river flowing in at the same time in very small quantities.

To gather these side springs, a collecting gallery, about 570 ft. long, was constructed between the right side of the valley and the river. It was placed at a level, so as to cause the water to come up through the most pervious strata of the subsoil, lying above the

granite ledge. It was also planned that the level of the water in the wells, in which the collecting gallery empties, was to be lowered only so deep that the water-table extending from the well toward the river Rhine should not intersect the river below its water level. Even if this were exceeded, and if the water-table would intersect the water level of the river, the river water would flow into the underground strata only upon causing a pressure sufficient to overcome the impervionsness of the fine sand and silt on the sides of the bed of the river, and lying between it and the coarse gravel in which the collecting galleries are built.

As the water level of the river falls, this situation becomes more favorable. The underground springs whose water-table is fixed by the level of the river, flow at a velocity due to the increased head into the gravel beds of the valley; the flow of spring water upwards into the Elbe through its bed is also greater, and the possibility of intercepting independent ground-water is correspondingly greater and more likely than an infiltration of river water. Circumstances are different when the river level rises rapidly. The water-table cannot rise with equal quickness, but is, after a few days, dammed up by the freshet level of the river. During this damming up, and until its conclusion, the water of the river will penetrate the subterranean layers of the shores, so long as the same are not saturated with spring water, or in so far as it is not kept out by impervious layers of soil. This wave of dammed-up water, in case of a small increase of the river level, is often at a higher level than that of the river, and the river water cannot penetrate very deeply into the soil.

When the collecting galleries are heavily drawn upon, the surface of the water-table is, of course, lower than the level of the water in the river, and greater heads obtain which might force the river water to penetrate the subterranean layers of the river channel. It appears, however, that during continued high water the indications from which a penetration of filtered Elbe water into the ground-water could be inferred obtain only during the first few days; and even during long periods of high water (in 1876, 120 days) these indications disappeared completely after three or four days, and the normal conditions again obtained. For a long time it was supposed that the fine opalescence, which appears during the first few days of a quick-rising high water, was due to the same; but these indications appear so seldom, and for

so short a space of time, that they were deemed of no importance. Closer examinations, instituted within the last five years, have shown this slight opalescence to be caused by an infiltration of Elbe water entering through detached porous places of the masonry lining of the well, and the effect disappeared as soon as the ground-water rose in due proportion to the high-water level. This opalescence has disappeared almost entirely since the masonry of the wall was uncovered in the year 1891 and carefully cemented, and it is to be expected that upon the completion of the work, which can only be done during the summer, and at very low stages of the river, it will disappear entirely.

On account of the short distance of the steep hills from the shore of the Elbe on the right bank of the river, collecting galleries could not be placed a sufficient distance from the river to bring them outside the region of overflow by high water, and considerations of river conservancies did not permit water-tight well masonry to be placed above the high water-line, or to raise up the site of the collecting gallery, which is under water whenever the river is 5 ft. above zero of the Dresden river gauge.

The water of the Elbe and the Moldau carries, in times of rising water, a great quantity of seepage from layers of turf in the upper regions of the river, which give it a yellowish brown color, due to the iron and to the acid in the turf, which filtration fails to remove. Hence, in the first few days after the beginning of a quick rise of the river, the water distributed in Dresden will show a slight yellowish discoloration, which disappears as soon as the ground-water has been dammed up. This shows that during this short time filtered river water has penetrated into the subsoil and into the ground-water.

Chemical analyses, regularly instituted during times of high water, has shown that the good quality and clearness of the Dresden water does not suffer during continued high water of the river. The continued analyses also by the Government Chemical Central Laboratory, which has admittedly undertaken the work of proving by its labors that the water delivered by the Dresden water works is merely filtered Elbe water, have shown, and the Laboratory has been obliged to confess, that this proof cannot be furnished. The fact that the water of the Dresden water works is subject to considerable fluctuations of temperature has given rise frequently to the assumption on the

part of those not acquainted with the facts of the case, that for this reason the water may be taken to be merely filtered Elbe water. Figures giving the maximum and minimum temperature are, however, frequently given undue weight, because great fluctuations of temperature are due to the special inflow of high water, and disappear quickly with the high water that caused it. If the collecting galleries were far enough distant from the bed of the river, and beyond the reach of inundation, only a very small variation of temperature would be noticeable. But, even during the first few days of the quickly rising water from the river, during which time the effect of the Elbe water must be admitted, the temperature of the water in the pipes does not approximate to that of the river, which would have to be the case when drawing from 7 500 000 to 10 000 000 galls. per day for months at a time, if the ground-water did not exert an influence of its own upon this temperature.

In January, 1893, the water of the distribution pipes had a temperature of 47° Fahr. (8.2 Cent.) at a time when the adjoining portion of the river was covered with ice, and its bed, also, was in part covered with ice. The cause of the variation of the water in the pipes is to be found in the great effect of the neighboring river as a big reservoir of heat upon the water following the subsoil, and numerous investigations have shown that such variations of temperature occur, also, in the water of wells which are near the river, but the water level of which is higher than the water level of the river.

After consideration of all the circumstances, the builder of these water works advised that, having due regard to the preservation of the superior clearness of the water derived from them up to date, the amount pumped should not exceed 7 500 000 to 10 000 000 galls. in 24 hours, and that the construction of the works, as originally built, did not have for its object the lowering of the ground-water level to extreme limits. To enlarge the water works in the most rational manner, recourse should be had to finding a site on the left shore of the river, in which ground-water of good quality and in sufficient quantity could be found for a second water-works plant. By placing another pumping station on the left bank of the Elbe, the distribution of water, and the assurance of a proper capacity of the whole system, would be obtained in a very advantageous manner.

The principal portion of the city, the old city, has been supplied

hitherto from works through two pipes of 24 and 18 ins. diameter respectively, laid on the Augustus Bridge, and through two 12-in. pipes laid on the Albert Bridge. The pressure supplying the water from the high-service reservoir is that due to the consumption which was assumed when the distribution system was built. No complaints about lack of pressure have yet been made, even in the parts most distant from the high-service reservoir, in the south-western wards of the city, and even when the consumption has reached 10 000 000 galls. in 24 hours. But circumstances would be entirely different if the present pumping station should be enlarged, because the distribution pipes would then not be able to convey a larger quantity of water, or would not be able to deliver it to the consumers under a proper pressure. In that case, special mains would have to be laid from the high-service reservoir over the bridge and down into the heart of the old city, in order that the proper distribution of the larger amount of water could take place.

By building a new pumping station, the greater part of the city of Dresden, the old city, situated on the left bank of the Elbe, will become independent of the present water-works plant and of the mains crossing the bridges, and there will be a great deal more pressure in the rapidly growing old city than could possibly have been obtained by an extension of the existing water works.

The site for placing the new pumping station was chosen for various reasons, somewhat further up stream, between the suburb of Blasewitz and the town of Tolkewitz, on the Tolkewitz meadows, rather than directly opposite the present water works. This was done partly, to get beyond the reach of the rapidly growing town of Blasewitz and to go up stream from the newly located cemeteries, and partly on account of the quality of the water found in bore holes on the left bank of the Elbe. As has already been mentioned, the borings directly opposite the present water works yielded a ground-water which was a few degrees harder than the water of the Elbe. This greater hardness, due to the influx of the water of lateral springs from the chalk formations of the left side of the valley, diminishes as one goes up stream. A well dug for the Court Brewery in Cotta, on the immediate banks of the Elbe, yielded a materially harder water than that of the river itself, when about 40 000 galls. in 24 hours were pumped from it.

The amount of hardness of the water on the left side of the river may be seen by the following figures:

Water from—	Degrees of Hardness.
The existing water works	7.5
The Elbe	12.0 to 13.0
The bore holes in Blasewitz, on the left bank of the Elbe, opposite the present water works	14.0
The well of the Court Brewery in Cotta	22.0
The well in the "Old Market," in the old city, Dresden	35.0 to 36.0
The well on Vienna Street	40.0 to 41.0
The well on Berg Street	56.0
The well of the new water works	10.0
The well in Tolkewitz	10.0
The well in Blasewitz, according to the depth of the well	10.0 to 12.0 to 16.0

An extended series of examinations of this sort demonstrated that the hard ground-water flowing from the left side towards the middle valley of the Elbe and towards the river, did not flow in a direction at right angles with the center of the valley, but went under the old city of Dresden, and reached the channel of the Elbe, down stream from the same.

The fact that the hardness of the well water in Blasewitz is different in different wells is explained by these wells having different depths. The subsoil in Blasewitz consists of a stratum of sand some 26 ft. thick at the surface, then one of clay 6 to 10 ft. thick, and, under this, the water-bearing gravel of the Elbe valley.

The wells dug in the principal layer of sand, and ending above the layer of clay, have a harder water, while the wells reaching into the gravel beneath the layer of clay yield a softer water. From these examinations, it was shown that the proposed site of the second water-works will furnish partly the water of the underground strata of the Elbe valley, and partly the lateral tributaries, coming in from the chalk, and in an easterly direction from the granite and syenite formations on the left side of the valley. Upon this, 35 borings were put down, which showed a very uniform formation of the subsoil, from which the inference was drawn that the same formation extends over a still greater portion of the left Elbe valley.

The surface of the proposed site, situated on an average of from 13 to 16 ft. above the zero of the river gauge at Dresden, consists of meadow and farm lands, in which is found a clayey sand about 13 ft. thick and so impervious that the ground-water from beneath rises some 10 ft. high in the bore holes after these layers have been penetrated. Under these impervious layers is found sand, which, at a greater depth, is mixed with gravel and boulders, until an impervious layer of blue clay is reached, at a depth of 50 to 53 ft.

Chemical analyses was made of the water derived from the bore holes; and these showing a sufficiently favorable result, the putting down of a trial well was begun. This well was lined with cast-iron slotted cylinders, 16 ft. in diameter, double dipped in asphalt. The lowest cylinder had a thick cutting edge, and was followed by three of the slotted cylinders, each 3 ft. 4 ins. high. Upon the topmost was placed a flat ring, and on this the masonry lining of the well was built up to the surface in a water-tight manner.

This well was put down to a depth of 43 ft. beneath the surface of the ground, by means of dredging under the cutting edge. After its completion water was pumped from it to the amount of about 1 250 000 galls. (5 000 cu. m.) daily for several weeks, day and night, during which time the well yielded, on demand, by means of an increased lowering of the water level, up to 2 000 000 galls. in 24 hours. The level of the water-table was determined during the regular pumping of 1 250 000 galls. in 24 hours by means of measurements in bore holes put down in lines, each parallel to the other, and at right angles to the river. In determining upon a proper depression of the level of the water in the well, the rule was observed not to allow the water-table to intersect the level of the water of the river itself.

During these examinations, it was shown that the subsoil was very solidly packed, and the water-table, when the water in the well was lowered from 20 to 23 ft., and only drawing 1 250 000 to 1 500 000 galls. in 24 hours, would slope sharply toward the well, and would gradually curve over, so as to join the original water-table at a distance of 260 to 300 ft. from the well.

An examination of the quality of the water taken from the bore holes and from the trial well was made in two laboratories, in the Government Chemical Central Laboratory at Dresden, and in the chemical laboratory of Dr. E. Kayser, of Dresden.

The table on page 326 will show the result of such chemical analyses.

According to these analyses, the ground-water thus discovered is of exceptional purity, due to the very small quantity of organic substances contained and the absence of every trace of nitrous acid and of ammonia. The amounts of all the other substances contained are less than the limits which have been fixed for the determination of a supply of pure and wholesome water, and it may be assumed, as indicated by a comparison of the analyses of the samples taken on November 7th and 12th, that these quantities will be still further reduced by continued pumping, and by covering over the well, because they are derived partly from the lining of the well, and partly from the unavoidable accident of substances getting into the well from above.

The maximum amount of ground-water could be drawn on the site selected, by the construction of a collecting gallery, similar to the one put down at the present water works, at a depth of 16 to 20 ft. But it costs a disproportionately great sum to build such a gallery at a depth of 40 to 43 ft., as would have to be done on this site. The plans, therefore, are to put down a row of deep wells, somewhat after the manner in which the trial well was put down, to string them along the site in question, and connect them with the new pumping station. This station will be placed on the site between the Blasewitz-Tolkewitz and the Dresden-Tolkewitz Street, and above the high water-line of 1845. It is for the present to consist of two steam pumps, each of 5 000 000 galls. capacity in 24 hours, provision being made for placing two other steam pumps of this capacity. A force main of 28 ins. diameter (interior) will be laid through the eastern part of the old city to the reservoir to be constructed on Räcknitzer Hill, holding about 3 000 000 galls. It is intended to lay a second force main of the same diameter and build another reservoir of the same capacity at a later day. The distribution system of a portion of the old city will be connected with these force mains.

The high-water level of the new reservoir is nearly the same as the high-water level of the reservoir at Fish-House, on the right bank of the Elbe, which has a capacity of 5 000 000 galls.

Water is to be pumped directly into the old city from the new water works through the force mains, and to connect with the old city distribution pipes.

A — From Bore Hole No. 18.				B — From the Trial Wells.				From Present Water Works.
Date when Samples were Taken in 1892.								
August 12.	November 7.	November 7.		November 7.	November 21.	November 7.	November 21.	August 12, 1891.
Analyses by—								
Dr. Kayser.	Dr. Kayser.	Government Chemical Central Laboratory.		Dr. Kayser.	Dr. Kayser.	Government Chemical Central Laboratory.	Government Chemical Central Laboratory.	Government Chemical Central Laboratory.
One liter of water (1 000 gr.) contains:								
Gram. 0.2244	Gram. 0.2014	Gram. 0.1902	Solid matter in solution.....	Gram. 0.2260	Gram. 0.2010	Gram. 0.2074	Gram. 0.2028	Gram. 0.1569
Of which—								
0.0012	0.0015	0.0001	Organic substances.....	0.0035	0.0011	0.0004	0.0001	0.0020
0.0230*	0.0204	0.0141	Chlorine.....	0.0213	0.0195	0.0153	0.0145	0.0113
0.0433	0.0336	0.0278	Nitric acid.....	0.0362	0.0282	0.0297	0.0297	0.0096
0.0485	0.0490	0.0450	Chalk.....	0.0524	0.0513	0.0510	0.0474	0.0422
0.0113	0.0129	0.0113	Magnesia.....	0.0142	0.0149	0.0125	0.0123	0.0124
	0.0276	0.0275	Sulphuric acid.....	0.0358	0.0345	0.0356	0.0334	
	0.0140	0.0187	Salicic acid.....	0.0146	0.0152	0.0181	0.0190	
	0.0154	0.0220	Fixed carbonic acid.....	0.0163	0.0149	0.0216	0.0202	
			Potassium.....	.....	.....	.....	0.0058	
			Soda.....	.....	.....	.....	0.0266	
			No ammonia.....					
			No nitrous acid.....					
			No phosphoric acid.....					
6.7	6.7	6.08	German degree of hardness.....	7.2	7.1	6.85	6.46	5.96

A From Bore Hole No. 18.				B From the Trial Wells.				From Present Water Works.
Date when Samples were Taken in 1892.								
August 12.	November 7.	November 7.		November 7.	November 21.	November 7.	November 21.	August 12, 1891.
Analyses by—								
Dr. Kayser.	Dr. Kayser.	Government Chemical Central Laboratory.		Dr. Kayser.	Dr. Kayser.	Government Chemical Central Laboratory.	Government Chemical Central Laboratory.	Government Chemical Central Laboratory.
From the figures above given, the amount of substances dissolved in 1 liter of water are as follows :								
	0.0469	0.0468	Sulphate of lime	0 0609	0.0586	0.0605	0.0568	
	0.0350	0.0459	Carbonate of lime	0.0371	0.0254	0.0466	0.0428	
	0.0215	.....	Silicate of lime	0.0229	6.0248			
	0.0029	0.0187	Free silicic acid	0.0028	0 0024	0.0181	0 0046	
	0.0460	0.0381	Nitrate of magnesia	0.0496	0.0386	0.0407	0.0407	
		0.0021	Carbonate of magnesia	.....	0.0072	0.0021	0.0026	
	0.0020	.....	Chloride of magnesia	0.0027	0.0043			
	0.0312	0.0232	Chloride of sodium	0.0318	0.0268	0.0252	0.0239	
	0.0015	0.0001	Organic substances	0.0035	0.0011	0.0004	0.0001	
			Silicate of soda	.....	.....	.....	0.0218	
			Silicate of potash	.....	.....	.....	0.0093	
	0.0144	0.0153	Crystal water	0.0147	0.0118	0.0138		
	0.2014	0.1902		0.2260	0.2010		0.2028	

* Common salt 0.0380 gr.

The new pumping station is designed for a maximum consumption of 15 000 000 galls. in 24 hours, so that the two water works of the city of Dresden will have a joint capacity of 27 500 000 galls. in 24 hours.

The experience of the year 1892 has shown that great caution should be exercised in determining upon the actual amount of consumption. The long-continued drought of that year caused an excessively large use of water, and but few water works were in a position to meet the same. It was found that the maximum consumption in that year in Dresden, was over 40 galls. per day per head, and the water-works had to restrict the amount supplied to the public fountains, so as to provide for the event that the consumption would increase still further.

Inasmuch as the time of maximum consumption coincides very nearly with the period of the lowest yield of ground-water, it is necessary, in designing works of this kind, to compare the maximum consumption with the minimum yield, instead of with average quantities, as is often done. The copious yield of some water works, at times of the year when there is only a small consumption, has no value, because it is impracticable to store water to the extent of utilizing it during the warm months of the year, as has been shown by experience.

In the case of many water works, statistics have shown that the maximum consumption per head of the inhabitants supplied by the works, has been, on many days, considerably greater than the above-named measure of 40 galls. per day, and it will be necessary in computing the available quantity to provide for larger figures.

The above-cited examples are sufficient, without mentioning the great number of smaller works for smaller cities, to show to what extent the use of ground-water has established itself in the last 25 years, and it may only be mentioned in conclusion that the author has been called, in conjunction with Mr. O. Smreker, Civil Engineer, of Mannheim, to make plans for furnishing the city of Vienna with ground-water, in addition to its high spring aqueduct.

These works are to be of a capacity of 50 000 galls. per day, and are to be designed so that they may be increased to a capacity of 100 000 000 galls. Mr. von Wessely, of Prague, principal of the firm of Corte & Co., contractors, of Prague, has been charged with the conduct of the preliminary borings.

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648.

(Vol. XXX.—November, 1893.)

SOME QUESTIONS CONCERNING THE FILTRATION OF WATER.

By W. KÜMMEL,* C. E., Engineer of Gas and Water Works Company at Altona, Germany.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

The Imperial Board of Health in Berlin was led by the violent epidemic of cholera in Hamburg to compile, some months ago, the principles derived from the experience of water works with sand filtration, in order to avoid infection when cholera is prevalent.

These principles, translated in somewhat abridged form, run thus:

First.—Care should be taken that the rivers, ponds, etc., from which the water is derived be safely protected against pollution by human dejections; no vessel, barge, etc., should be allowed to anchor near the intake of the water works.

Second.—Sand filters do not deliver the water totally free from microbes; they restrain only a certain number of them, including the

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* Died at Chicago, July 19th, 1893

microbes of the cholera; therefore the filters should never be overworked.

Third.—The velocity of filtration ought not to exceed 4 ins. (100 mm.) per hour.

Fourth.—If the quantity of water consumed in the town surpasses the quantity that can be delivered by the existing filters at the said velocity, the water works have to remedy the defect, either by reducing the consumption (introduction of water meters) or by building new filters.

Fifth.—The stratum of the filtering sand should never be less than 12 ins. (30 cm.) thick.

Sixth.—When a filter has been cleaned, or filled up with new sand, it is necessary to waste the first filtered water, with its high number of germs, and not deliver it to customers.

Seventh.—The effect of filtration must be daily controlled by bacteriological tests of each filter. If the bacteriologist finds suddenly a greater number of germs, or unusual species of microbes, in the filtered water, such water should not be used at all.

Eighth.—If these principles are carefully followed, the danger of the microbes of cholera passing through the filtering sand-stratum is exceedingly small, as has recently been proved by the Altona water works compared with Hamburg.

The author of this publication is believed to be the celebrated Doctor Robert Koch, at Berlin, the discoverer of the microbes of phthisis and of cholera, who has for many years been making inquiries into the effect of filtration, and these rules are, therefore, the result of a large experience. The writer is sure that the majority of his colleagues who are busy with filtration will, in conformity with their own experience, accept most of them; but some will be in doubt whether all the rules are exactly correct.

The publication of the Board, really a governmental order in Germany, settles the maximum velocity of filtration not to exceed 100 mm. per hour, or 2.40 m. per diem, equal to a delivery of filtered water per square meter per diem of 2.40 cu. m.; that is, 4 ins. per hour or 8 ft. per diem velocity, and 60 U. S. galls. (50 imper. galls.) delivery per square foot per diem in English measures.

As far as the writer is instructed about the rate of filtration now used in English water works, he finds these numbers corresponding

with those in use there, as an average in some works, but as a maximum in others. It is not very many years ago that in England the average quantity of filtration was about 50% more than 8 cu. ft. per square foot of the filtering area; and this quantity has been delivered in Germany, too, chiefly by water works having a water with few earthy ingredients. Why shall we take the 4-in. velocity as a standard for a safe and sure filtration?

Mr. Bertschinger, chemist and bacteriologist of the corporation of Zürich, published a paper in 1889 concerning "The Working of Sand Filters in Zürich." In this paper he states, from a long series of trials, "that the result of the filtration is equal to velocities of from 2.7 to 13.4 m. (or from 9 to 44 ft.) per diem."

Mr. Piefke, engineer of the Stralau station, Berlin water works, writes in 1887* that his filter delivers the water nearly sterile at a velocity of 30 mm. per hour, or 30 ins. per diem; that the velocity of 60 to 80 mm. per hour, or 4 ft. 9 ins. to 6 ft. 4 ins. per diem, would be for his works tolerable; but 100 mm. per hour, or 8 ft. per diem, should be the maximum for new works. Notwithstanding, it is stated in another paper, issued by Dr. C. Fränkel and Mr. Piefke, that on March 12th, 1889, the Stralau water works filtered with a velocity of 224 mm. per hour, or 17 ft. 11½ ins. per diem. The bad working of the filters has caused the authors named to make a series of trials with pathogenic and non-pathogenic microbes, from which they have stated that the pathogenic microbes pass the filter even at a very low velocity of filtration; but—it may be added—under the supposition that the raw, unfiltered water be mixed with the microbes at the rate of 500 to 700 per cubic centimeter, and the filter be ill-treated as it was by the authors of these tests. Messrs. Fränkel and Piefke conclude from their experiment that filters should not be worked with a velocity exceeding 50 mm. per hour, or 4 ft. per diem.

Mr. Piefke two years later repeated the experiments, without repeating the mistakes of the first series. The result was nearly the same; but he worked again with a water containing a number of pathogenic microbes, such as we can absolutely not find in a polluted river or pond used for water delivery.

The writer himself has also made a great number of trials to find the best velocity for the filtration of our water. To avoid every error

* Principien der Reinwasser-Gewinnung mittelst Filtration.

or mistake resulting from the difference in the quality of the unfiltered water, he built three experimental filters, filled with the same filtering materials, all conditions being exactly the same, only the velocity of filtration being different. As soon as the three filters were in good condition the experiment began, the water running through the filters at a velocity of 50, 100 and 200 mm. per hour, or 4, 8 and 16 ft. per diem. The result was that the number of microbes in the filtered water was, without exception, the highest in the water of 50 mm.; averaging, higher in the water of 100 compared with that of 200 mm., but really there was no great difference between the three. The number of the microbes varies in the 50-mm. water from 11 to 97; in the 100-mm. water, from 5 to 79; in the 200-mm. water, from 7 to 72, per cubic centimeter. The difference is not sufficient to declare the one velocity better than the other, and therefore the writer cannot agree that the velocity of 100 mm. is, beyond doubt, the maximum of safe filtration. Notwithstanding, the writer accepts this standard as long as better experiments do not prove it to be false, because he believes the danger of a trespassing pathogenic microbe is much more trifling at the lower than at the higher velocity; and, besides, that the best velocity is not the same for all different qualities of water. He is sure that the difference in the mineral, vegetable and animal admixtures is of high importance in this question, and that we should endeavor to find out the best velocity for each separate water and water works.

A second point that is often disputed is contained in Clause 6. According to the present state of science and experience, it is generally accepted that the thin film of dirt on the surface of the sand is really the filtering medium, and that the filters, filled up with new sand or cleaned, do not properly work before a new film of dirt has been gained. Mr. Bertschinger's experiments show that the Zürich filters do not do their full duty until four to seven days after the cleaning. Mr. Piefke's experiments at Berlin show the filter fully restored after four to five days' working. The unfiltered water in Zürich is of a first-rate purity compared with the water of the Spree in Berlin and of the Elbe near Altona. The raw Zürich water contains generally less than 300, in very rare cases 400, germs, the water of the Spree generally some thousands, very seldom more than 10 000 germs, while the water of the Elbe at the Altona water works contains exceedingly seldom less than 10 000, generally more

than 20 000, and very often more than 40 000, germs per cubic centimeter. On the other hand in the Elbe water the amount of mineral substances is very high, the amount of vegetative matter very low, compared with the Spree water. The mineral matter subsides very fast, as soon as the water is brought to rest. The writer, therefore fills up the cleaned or newly filled filter in the usual way from below with filtered water to the top of the sand, and afterwards with unfiltered, subsided water from above, and then gives a sufficient time for the mineral impurities to subside on the surface of the sand. Generally six to eight hours, sometimes 10 or 12 hours after the time the filter is filled with water, the filtration begins and is quite satisfactory, the number of microbes being not, or very little, increased, as compared with the water filtered before the cleaning.

Quite a different case is that after the filling up with new sand. If we proceed just in the same way with the inlet of water, and give the raw water a time of 20 hours of quiet rest, the number of microbes becomes very high, as the following figures may show :

	Number of microbes.	
Before the filling up.....	42	24
One day after filling up.....	1 880	2 300
Two days after filling up.....	752	1 364
Three days after filling up.....	208	468
Four days after filling up.....	156	244
Five days after filling up.....	102	82
Six days after filling up.....	84	116

It is certain that the working of the filter, when filled up with new sand, is for a certain time not satisfactory ; therefore, we must waste the water during the first three or four days unused.

A third point to be discussed is contained in Clause 7 ; it is not sufficient to examine the water as it is delivered to customers ; the water running from each filter must be every day tested bacteriologically. We have made arrangements, to take the samples from each filter, as near as we could get. At first there were attached to the outlet pipes, short lead pipes with bib cocks, and the water was drawn from these cocks, about 2 ft. from the mains. That was a mistake ; some days after the first trial the lead pipes were grown full with microbes, and the samples of water taken from the bibs, though full care was taken to have the water from the mains, did not show the

latter, because the running water washed away many of the colonies in the lead pipes. Now the arrangement is altered; we take the water directly from the main with a sterilized short pipe, introduced in the main through a properly constructed stop-cock.

We find it a very good thing to examine every day each of the filters, and we are sure that we save ourselves a great many mistakes and much mischief by this very simple and very safe expedient. Without this bacteriological examination we are working just like a mechanical engineer who does not indicate his steam-engine, thinking that he is able to estimate its quality from the revolution of the fly-wheel.

The only thing we have not to overlook is that the number of germs found in a cubic centimeter is not very important in itself, but only a means and way to find out the good working of a filter. As soon as we find that the number increases suddenly, we may be sure that something in our filter is out of order, and we have to do our best to search and repair the fault.

A point of much greater importance is the determination of the species of the microbes; in each sample of a good filtered water the number of species will not exceed five or seven, and these species will not vary very much, though different species predominate at different seasons. As soon as we find that the water contains some well-known species of microbes of the liquefying type, we have to examine the colonies in the discs and the filters with the utmost care.

If we do so, we may be sure that we are able to deliver a good safely usable filtered water, even from a river not at all protected against pollution through human dejections.

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649.

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ON THE DISTRIBUTION OF WATER IN THE CITY OF MEXICO.

By L. SALAZAR, M. Association of Engineers and Architects of Mexico.

Translation.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

Sources of Supply.—Tradition has fixed the year 1465 as the epoch in which the works were completed for bringing to the city of Mexico the water from the springs of Chepultepec, declaring that the enterprise was fathered by Metzahualcoyotll, who, it is said, did the leveling.

Two springs, called, respectively, Alberca Chica and Alberca Grande, are certified as actually belonging to the municipal dominion. The water which they produce is denominated "heavy," in distinction from the water of the Desert, called "light," from its lighter density. The

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"heavy" water of Chepultepec is transparent, of a bluish color, and has an average temperature of 21.5° Cent. Its density is 1.00084 referred to that of pure water at 0.76 m. above sea level and 4° Cent. According to the learned Mexican chemist, D. Leopold Rio de la Loza, the analysis of the heavy water gave him the following result:

Gaseous products:

Air	10 390
Oxygen	1 760
Carbonic acid	0 990
Total in cubic centimeters per liter	13 140

Solid products in grams per liter:

Sulphate of lime	0.00652
Carbonate of lime	0.02712
Carbonate of magnesia	0.02215
Carbonate of soda	0.03901
Chloride of soda	0.05845
Silicate of soda	0.02997
Acetate of potash	0.02158
Silica	0.07745
Alumina and iron	0.00686
Organic matter	trace.
Lost	0.00093
Total in grams per liter	0.29004

Temperature in the springs, 22.5° Cent.; density, 1.00028

The two Albercas contain great numbers of small fish, called by the Aztecs, "Fentzonmichi," whose existence and facile development in the springs is one of the most important biological features of this potable water.

The water of Chepultepec was considered insufficient for the necessities of the population from the first years following the conquest of Mexico. It was on this account that, in 1576, the water from the springs of Santa Fé was introduced into the city, first, by a channel

in masonry, and afterwards, in the ditch or aqueduct of San Cosme, which was completed in 1620.

The works for carrying this water were of considerable importance on account of the broken nature of the ground, where they are developed. The conducting channel is notable for the epoch in which it was built; the water-conducting bridge, 30 m. high and 37 m. long, which was finished in 1734, and the grand arcade, composed of more than 900 arches of stone masonry and light brickwork, having each a span of 6.70 m., with 55 m. of height and 1.46 m. of thickness, the canal being 0.63 m. deep and of equal width. At the present time this aqueduct has disappeared within the western limits of the city.

The Santa Fé spring is 10 km. from the city of Mexico and 166 m. above the level of the city. The temperature of the water in the spring is 15° Cent.

From the end of the last century, in 1786, there have been added to the waters of Santa Fé, those of the springs of the Desert and Los Leones brought from their source in the western wooded district of the valley, about 25 km. distant from the city. All this water is designated as "light," to distinguish it, as already explained, from that of Chepultepec, which has been called "heavy." The waters on leaving the springs are diaphanous, but, being stirred up in their passage through the aqueduct, become turbid and require filtering before use, especially in the rainy season, since at some points the canal, not being covered, the dust in the atmosphere reaches it, and also earth loosened by rains at the head.

The springs of Los Leones have their origin in the mountain of San Miguel. There are many little springs disseminated in all directions, which are caught in their natural channels by the dam of Los Leones, where the works of masonry begin, and where also the waters of the Desert are gathered.

The distinguished Mexican engineer, Señor Don José Salazar Illaregui, who was the chief of the Boundary Commission with the United States of America, did the leveling and designed the plans of the work from the city to the dam of Los Leones, the starting point of the work being the first arch of the aqueduct in the Avenue of La Veronica, the plane of comparison being the bottom of the superior canal. The results were as follows:

	Distances. Meters.	Heights. Meters.
Arch of La Veronica (Initial Station)..		
Aqueduct Union.....	1 408	2.09
Mill of Belem	6 980	128.35
Springs of Santa Fé.....	9 716	166.18
Angostura.....	11 970	340.79
Tres Cruces	19 582	672.71
Junction of the canals	19 732	680.80
Head of the Desert aqueduct.....	24 932	859.49
Head of Los Leones aqueduct.....	24 580	904.21

The springs in the mountain of San Miguel are still higher than the last mentioned by 27 m.

The analysis of these waters by Señor Leopold Rio de la Lozo, already mentioned in treating of the Chepultepec Springs, gave the following results, viz.:

Temperature at the sources being 9° Cent.; density, 1.000267.

Gaseous products, in centimeters per liter:

Air	10.151
Oxygen	2.809
Carbonic acid	0.750
Total.....	13.710

Solid products, in grams per liter:

Sulphate of lime.....	0.00326
Carbonate of lime.....	0.02171
Carbonate of magnesia.....	0.01169
Chloride of potassium.....	0.00396
Chloride of magnesia	0.00349
Silicate of soda.....	0.03985
Silica	0.05169
Alumina and iron.....	0.00849
Organic matter	0.00087
Total	0.14501

The northern district of the city, known as the Santiago Tlaltelolco Ward, was provided with water from the springs of Motlatica or Xancopinca. In 1618 these waters had been already mentioned by a historian of the epoch, and at the end of that century were still used in the supply of the city, according to the Franciscan chronicler, Betantourt. Whether it be that the pavement of the zone supplied by the water of Xancopinca has sunk, or that the spring has lost (in some other way) its ascensional force, the fact remains that this water no longer arrives at Tlaltelolco, this being one of the causes of the decadence of that ward.

In 1847 Dr. Leopold Rio de la Loza examined said water and found it superior to the heavy water, since its density was 1.000201 and it contained only 0.15011 of fixed substances in 1 000 parts of the liquid. The color of the water and its transparency are similar to the others of which mention has already been made. The temperature in the spring is 21.50° Cent.

The spring, on account of the duration of time in which it had been abandoned, reverted to the possession of private owners, being claimed by the abuttors. The Municipal Council of 1892 succeeded in re-establishing the rights of the city and at the present time are occupied in constructing the works necessary to restore the waters to the district which formerly enjoyed their use.

The increase of population in the wards known as Santa Maria Guerrero, Los Angeles, Santiago, Tlaltelolco and Santa Anna, and the almost absolute want of water in the district, induced the Municipal Council of 1882 to acquire by lease a part of the water that supplied the city of Guadalupe Hidalgo. That water proceeds from Tlalnepantla, 13 km. distant from Guadelupe, and its aqueduct was constructed in 1743–51 at a cost of $129 000, collected by popular subscription.

From the city of Guadalupe to Mexico the pipe line was laid in the short space of 95 days, and for the first time in our history the material was of Mexican manufacture, giving advantages both in its superior quality and in its cheaper cost.

The introduction of this water into the city of Mexico was inaugurated on April 2d, 1882, realizing thus an important improvement for one of our most populous neighborhoods, which has had a notable advance in population since that event.

It could not fail that the experiment of artesian wells should be tried in Mexico, and it has fallen to Messrs. Pane & Molteni to be the first to have achieved success in such work, which has given them the best results. The persistency and labor of the gentlemen conquered all the difficulties of an enterprise entirely experimental, and in May, 1857, they could count 168 of these wells opened, of which 24 were intended for irrigation, 120 belong to private houses, while 24 sunk by other contractors produce conjointly 690 cu. m., 639 liters per hour.

According to the data collected by the Government in 1883, there existed at that time 483 artesian wells, distributed in the city as follows:

1st Ward.....	24	5th Ward.....	40
2d "	55	6th "	39
3d "	61	7th "	47
4th "	40	8th "	177

The advance made in the opening of artesian wells shows the favorable conditions of the ground for the perforation of this class of works. The waters from these subterranean springs are as good as the potable waters already described, inasmuch as they proceed from springs situated outside the influence of the infected waters near the surface. The augur penetrated 234 m. in the well opened in the Military Hospital, and depths of 150 m. are by no means rare. The well sunk in the Mint in 1871 reached a depth of 149.162 m., and is one of the best exposures for the study of the geology of the region. Thirty-nine different strata are passed in which the permeable alternate with the impermeable, while the lacustrian condition of the deposits remains the same as in the running streams. In this well are three principal gushing springs at the depth, respectively, of 62, 104 and 141 m. The strata containing springs are in sand and overlie the argillaceous.

Water from the well of Bucareli was analyzed by Dr. Leopold Rio de la Loza, with the following results:

Gaseous products:

Air and oxygen.....	13.15	Carbonic acid.....	1.18

Being a total of 14.33 cu. cm. per liter.

Solid products in grams per liter:

Carbonate of lime.....	0.01130	Silicate of potash.....	0.01040
Carbonate of soda.....	0.06949	Silica.....	0.04515
Chloride of potassium.	0.00086	Alumina and iron.....	0.00276
Chloride of magnesia..	0.00091	Organic matter.....	traces.
Silicate of soda.....	0.08375		

Making a total in grams per liter..... 0.12462

The average temperature of water in the wells has been found at 15.5° Cent.

The number of artesian wells actually in use in the city of Mexico to-day is 331, which, however, do not contribute all they ought to the general supply, since their product is applied exclusively to the use of the property on which they happen to be placed, leaving the surplus flow to be wasted.

Quantities of Water.—The works that have been published concerning the water supply of the city tell us what is the character of the spring and spouting well water, which has been given the population. Only in 1857 Mr. Pane gave the following figures indicating the volumes of water in the various sources received by Mexico in cubic meters:

	Cubic meters.	Liters.
Superior aqueduct in La Cosme, light water.....	586	718
Inferior aqueduct, heavy water.....	287	117
Aqueduct of Belem, heavy water	363	058
Artesian wells.....	690	639
Total per hour.....	1 927	532

In 1864 Señor Don Manuel Orozso y Berra calculated the demand of the capital for water at 250 liters per day per individual in a population of 200 000. His figures were:

	Cubic meters.	Liters.
Waters, heavy and light.....	1 233	893
Waters of the artesian wells.....	866	895
Total used in the city per hour	2 100	788

In 1883 the data collected by the Government of the Federal District produced results as follows :

Light water.....	11 520	cu. m.	in 24 hours.
Heavy water.....	6 048	"	" "
Guadalupe water.....	1 152	"	300 liters, in 24 hours.
Total supply in 24 hours...	18 720		300 "

The water produced by the artesian wells does not enter into this account because so much of it is lost in waste and none of it is used for the general public.

Considering that the population of Mexico was 300 000 in 1883, this amount of water would give 64.4 liters to each inhabitant ; without reckoning that the volume of water so received has served, not only for domestic uses, but for the public service and for industries.

At the present time the water supply of the city has experienced notable modifications on account of the works executed for introducing it under pressure, a matter to be hereafter treated. This quantity is to-day as follows :

	Cubic meters.
Heavy water from the two Albercas of Chepultepec.....	25 920
Light water from the Desert, Los Leones and Santa Fé.....	10 080
Light water from Guadalupe Hidalgo.....	1 440
Gushing waters from artesian wells.....	7 690
Total supply in 24 hours.....	45 130

According to the census of 1890, the present population of the city of Mexico is 326 394. The quantity received as above noted does much more duty than supply this population with what it requires for its domestic use ; it is devoted to the irrigation of the streets, plazas and public gardens ; to extinguishing fires, washing houses, carriages and stables; also for animals used for work purposes, and in the industrial arts. Nor is it possible to estimate the quantity devoted to each kind of service, although it is well understood that there is a positive deficiency for general domestic use. This need has been emphasized in the present year by the increased pressure in pipes, which, being still a novelty, has not yet met the proper regulation in private houses.

The efforts of the Municipal Government are now directed to securing other sources of supply and perhaps the establishment of a double service, one for domestic uses exclusively, and one for the other uses above designated, as is the custom in the cities of Europe and the great cities of the United States of America.

Water-Courses and Conduits.—The light waters proceeding from the Desert, Los Leones and Santa Fé are conducted to the fall of the Molino del Rey in earthen pipes, following the topographical contours of the ground, except that, where the depressions are severe, aqueducts in masonry have been constructed, as already stated. Along the 25 km. of pipe line, as far as the Gate of the Tlaxpane, are the pueblos of Cuajimalpa, Santa Fé, Tacubaya, which use the water, as also the flouring mills of Santa Fé, Valdez, Santo Domingo and El Rey, the paper mills of Belem, the pin factories and the National Artillery Foundry at Chepultepec.

From the Molino del Rey fall, which the city acquired in 1891, the water continues its course in a pipe of 0.80 m. diameter, parallel to the old aqueduct from the woods of Chepultepec, and from La Veronica passing by Tlaxpana to the crossing of the front of the church of San Cosme. At this crossing the pipe line trifurcates and begins the distribution of the thin water supply for two-thirds of the city's area.

The heavy water produced by the springs of Chepultepec is raised by mechanical means to elevated reservoirs, hereinafter described, and from these is distributed according to the lines of the plan, which run parallel to the old aqueduct of Belem. At the Bucareli crossing begins the distribution of water for the remaining third part of the municipal area. The light water proceeding from Tlalnepantla, and acquired from the City Council of Guadalupe Hidalgo, comes in a pipe line from that town, following the wagon road, which starts directly from Pehalvillo. As already described this water supplies the district of the north of the capital, where it was difficult to take other light water under pressure before the construction of works lately executed.

The distribution of water in the city of Mexico presented great and grave defects until within a very few years. The pipes were of lead, of various diameters, recognizing no law, and were, moreover, deteriorated, principally by the water which leaked from them. The Municipal Council, recognizing the necessity of doing something to improve their very bad condition, and being without the funds required

for the undertaking, in 1880 called for a loan of $500 000 for the prosecution of this important work.

The project, which had been in the hands of the Council since 1868, had been made by the engineer, Don Casimiro Pacheco, and approved by the Commission appointed for the purpose, and also by the Water Commissioners of the Municipal Corporation. But the 12 years transpiring to 1880 had created new requirements, which demanded a change in the solution of the problem. There was, moreover, as a limitation to the work, the products of the loan already mentioned. Fortunately, the Engineer Director of Water, Señor Manual Patiño, had for 10 years employed himself in gathering data of a practical character, which now enabled him to present a plan commensurate with the requirements of the problem.

The Water Commission of the Municipal Council, presided over by the distinguished engineer, Señor Leandro Fernandez, made a minute study of the above-mentioned data, and formed a project, which was approved by the Council. As a base of the project, it was estimated that a supply could be counted on of 8 000 liters of light water, and 5 000 of heavy water, per minute, in accordance with which the city was divided into districts, the caliber of the pipes being arranged with reference to the slight declivities of the streets and the density of population in any district. The project was nearly abandoned on account of the failure of success with the loan of $500 000, but the efforts of General Carlos Pacheto, then Governor of the Federal District, opened the road for the enterprise. At his suggestion some of the municipal property was sold and the proceeds availed of to contract in England for 2 500 tons of pipe and accessories for the principal branches of the distribution. This work commenced in April, 1882, and continued without interruption under a plan more comprehensive than the project of 1880, the annual appropriations being as follows:

1881	$89 523	1887	$12 650
1882	185 456	1888	20 000
1883	179 662	1889	136 118
1884	56 485	1890	189 278
1885	11 752	1891	261 100
1886	34 864	1892	39 000
The total amounting to			$1 245 888

Meanwhile the disbursements were as follows:

1881.....	$51 302	1887.....	$41 486
1882.....	33 560	1888.....	48 706
1883.....	30 069	1889.....	61 140
1884	30 899	1890.....	117 905
1885.....	35 490	1891.....	177 732
1886.....	43 156	1892.....	134 347

The total of these disbursements were thus..... $805 792

The length of pipe line for the distribution of the various classes of water exceeds 100 km., the diameters of the varying sizes being for the principal lines 80, 60, 50, 40, 30 and 25 cm., respectively, while for the lesser lines they are 14, 12, 10 and 8 cm.

Also, there were placed at all street crossings the requisite gates, made in the machine shops of Mexico for facilitating repairs, without interfering with the general distribution. The same shops made the bronze faucets in use, and prepared the dead ends of pipes with lead at the entrance of the houses, for joining up the distribution within the domicil. The water is led by a principal pipe to the cistern, in which is arranged a safety cock (*llave economica*) with a float, to prevent the prodigal waste of the fluid. From this cistern the occupants of the house can make freely such distribution as suits them, with the sole proviso that they put a cock at the end of every branch in the house.

The operation of pumping is practiced only for the water of Chepultepec. That proceeding from the Desert, Los Leones and Santa Fé is found under conditions which permit its introduction to the city by gravity, running in pipes from El Molino del Rey, situated at an elevation of 26 m. above the average level of the city. The heavy water of the two springs of Chepultepec is collected in a tank beside the engine-house containing the pumps, by means of a pipe laid at the bottom of the springs, of 80 cm. diameter, whence, through pipes of 60 cm. diameter, it is raised to another reservoir 25 m. above the edge of the hill of Chepultepec, by three English-built Worthington pumps, with a capacity of 1 020 cu. m., each motor being of 70 H. P. These engines are of the kind known as "high pressure, direct acting, ex-

pansion, with condensers," each one possessing the ability to raise 12 cu. m. of water per minute under a head of 25 m.

The cylinders have the following dimensions: The high-pressure cylinder has 8 English ins. diameter, the intermediate, 13, and the low pressure, 21; all have the same length of stroke, viz., 18 ins. The pumps are of 17 ins. diameter.

Working under normal conditions, the engines make 45 revolutions per minute. The reducing valves are moved by levers connected with the piston valves by means of eccentrics (*engranes*). The valves are so arranged that the cylinders take steam throughout the stroke, the expansion occurring only by the passage of the steam from one cylinder to another, thus securing the greatest simplicity of construction and avoiding difficulty of adjustment. The valves on one side of the engine are moved by the trip of the opposite piston, and its combination permits the constant uniform flow of water. The condenser is of the type called *chorro*, and the pump for it is connected with the piston rods, as are also the principal pumps, which are double acting, and the valves of which are provided with springs. Each engine weighs 20 tons. The normal pressure of steam in the boilers is 100 lbs. per square inch. The normal velocity of the engines is 135 ins. per minute, which corresponds to the revolutions already noted. The motors consume 2 lbs. of combustible* per hour per horse-power developed. The combustible is brought from the woods of Desierto, property of the Municipality of Mexico, the exploitation of which is in charge of an agricultural professor (*agronomo*).

The building containing this machinery is in three divisions; the pump-room measures 35 ft. by 32; the boiler-room, 33 by 32; and the fuel-room, 32 by 32. The iron chimneys are 50 ft. high above the brick foundations on which they rest. The three pumps with their motors, boilers and erection, including the building in which they are located, cost $100 000, and were inaugurated December 29th, 1891.

Uses of the Water.—The potable water made use of by the city of Mexico is variously employed. It is understood that for drinking and domestic purposes it is necessary to employ salubrious water since hygiene demands that such water shall not contain germs prejudicial

* Nothing in the paper indicates the character of the "combustible," which is certainly not mineral coal, as it does not exist in the region. It is probably wood, though charcoal is a common fuel in the city of Mexico, and its transportation would be much less expensive than wood.—*Trans.*

to health, whether it be solely for drinking, for baths, for daily toilet use, or for washing clothes and other articles of domestic use. But for irrigation, for extinguishing fires, and for certain industries, it is a damage to use potable water unless the service can be regulated, since it often prevents the preferable utilization of the article for private health. In the city of Mexico these inconveniences are especially felt in the dry season, immediately preceding the rains, when the springs are reduced in their natural supply. Happily this trouble will last but a little longer, since the municipality will acquire in a very short time new supplies which will be conveniently distributed for private domestic use, in a system under a head of 25 m., not permitting the present enormous waste.

Water is delivered to private parties for the supply of their establishments through the medium of a rent contract, by which a monthly payment of $2.50 gives a *medio merced** of water, equivalent to 1.15 liter per minute, and which is the minimum volume prescribed for each house. When the water is delivered under a 25-m. head, the price will be advanced to $4. The supply of water may be augmented in any case in units of *medias mercedes* at the same proportional rents. At the present time there are 2 543 houses which employ and pay rent for light water, 1 860 which use the heavy water, and 116 which use the water from Guadalupe Hidalgo, being a total of 4 519 houses.

By some old concessions there are certain establishments which may use potable waters without payment of rents. There are 239 houses presenting such claims, but up to the present time the municipality has recognized only 175 of them. Free use of water is also conceded to the municipality and to those who have artesian wells in their houses, amounting in number to 234, as registered. Public edifices enjoy concessions for the free use of water, and also some private houses occupied by the Government offices or the municipality, while they are so employed. Public fountains for the free use of the people have been superseded by hydrants or other form of faucet placed at the edge of the sidewalks; they are generally a little column, with a faucet at the top. The fire hydrants are to be found at the corners of the streets. In the public gardens and parks the use of water is also gratuitous and sufficient for irrigation and the service of ornamental fountains. The arts make considerable use of the waters, there

* A localism explained in the context.—*Trans.*

being many establishments for the manufacture of articles of food and domestic use, while there are many manufacturers of cloths, hats and other subjects of the national industry using the water for their steam motors.

Conclusion.—This résumé has been brief, purposing only to give an idea of the service and distribution of water in the city of Mexico. The growth and importance of the city increases daily, and the quantity of water required for its use therefore increases. Thus it is that the Municipal Council, impressed with the necessity for fulfilling its obligations to the public health in the abundant supply of pure water, neglects no sacrifice, expense nor enterprise that has for its object the improvement of this important branch of the public service.

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PURIFICATION OF SEWAGE AND OF WATER BY FILTRATION.

By HIRAM F. MILLS, A. M., C. E.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

SIX years ago the State Board of Health of Massachusetts began experiments to supply the deficiency that was found to exist in the knowledge of the engineering profession upon the subject of filtration of water and of sewage. The ends in view were the prevention of pollution of streams, the purification of domestic water supplies and the general preservation and improvement of the public health.

The objects were not to make a better-looking water or one that would be better adapted for use in steam-boilers or for certain manufacturing purposes, but to learn the best methods of removing those impurities in drinking water that may be injurious to health, and, if

NOTE.—Discussions on all papers presented to the International Engineering Congress will be published simultaneously in the number for December, 1893.

possible, to purify sewage so that the effluent may with safety be turned into a drinking-water stream.

It appeared probable, from the experiments which had been made by Frankland and Warington, in England, and by Schlœsing, in France, and at the Clichy Laboratory, near Paris, that these objects could be accomplished by intermittent filtration. Their experiments, few in number, but giving astonishing results, were made in 2-in. glass tubes, in glass cylinders 10¼ ins. in diameter and about 5 ft. long, and in a glass tank 6½ ft. high and 8 ins. square. Diligent search at that time failed to find other experiments in which the chemical character of the effluent could be definitely compared with that of the applied sewage.

Excellent effluents had been obtained in the experiments on irrigation by the British Association for the Advancement of Science, and by Marié-Davy at Paris, and on irrigation fields in Germany, which might now be attributed to filtration ; but their purity was then regarded as depending to a great degree upon the action of growing crops. In these results Marié-Davy had shown a remarkable purification from bacteria.

There were, in 1887, various filter beds in use in England and on the Continent, mostly in connection with irrigation fields, or used, themselves, for growing crops. They were receiving from 36 000 to 90 000 galls. of sewage per acre per day, and were giving results satisfactory to the operators ; but the few published results of analyses of the effluents were less satisfactory than those obtained in the laboratories.

There was not sufficient knowledge upon the subject in the profession to enable a well-educated engineer to decide whether any selected area would purify sewage applied to it, and, if it would purify, the amount to be applied and the proper intervals for application, and whether and under what conditions disease-producing germs could be removed were unknown.

To supply knowledge upon these points and others pertaining to the purity of water supplies, the Experiment Station of the State Board of Health of Massachusetts was established at Lawrence in 1887. Some of the more important general results of the six years of careful investigation will now be presented.

A general description of the Station and the methods of investiga-

tion carried on there, together with the earlier results obtained, may be found in the published report on water supply and sewerage, entitled, "Experimental Investigations by the State Board of Health of Massachusetts upon the Purification of Sewage by Filtration and by Chemical Precipitation, and upon the Intermittent Filtration of Water. Made at Lawrence, Mass., 1888–90." Additional results may be found in the more recent "Annual Reports of the State Board of Health of Massachusetts."

A model of the Experiment Station, and samples of some of the sands used there, together with diagrams of some of the earlier results and samples of the sewage and of the effluents, may be seen in the south-eastern portion of the floor of the Anthropological Building, which is at the south-eastern extremity of the Fair Grounds.

Some idea of the extent of the laboratory work in the Department of Filtration may be conveyed by the following statistics.

There have been analyzed chemically :

1 700 samples of sewage applied to filters,
6 400 samples of effluent from filtered sewage,
400 samples of water applied to filters, and
970 samples of filtered water ; also,
611 samples of substances applied to filters and flowing from them, for the purpose of determining the effect of filtration upon various substances contained in sewage, making a total of 10 081 chemical analyses of samples connected with filtration.

Bacterial samples of sewage and effluent corresponding with 6 770 of the above chemical samples were examined, and about 4 000 such samples which were not examined chemically. Nine thousand other bacterial samples were examined in connection with filtration.

Samples of sand used in filters examined for bacteria numbered 880, making a total of 20 650 bacterial examinations connected with filtration. There have been made 3 700 comparative species determinations of the bacteria in water before and after filtration.

When this work was commenced it was definitely known that no nitrification, or complete oxidation of nitrogenous organic matter, would take place without a current of electricity or the presence and co-operation of organic life. Robert Warington had found by numer-

ous ingenious experiments that nitrifying organisms were to be found abundantly in soil, and it had been concluded that soil was essential to a filter-bed; but the experiments of the State Board of Health show that nitrifying organisms are contained in the several kinds of drinking-water supplies of all parts of the State and probably in all sewage, and that into filter-beds of sand or gravel containing no soil they are after a short time introduced in sufficient numbers by the sewage; hence, that soil is unnecessary for this purpose.

Organic life alone cannot produce nitrification; there must be present free oxygen. Unlike most drinking waters, sewage contains no free oxygen, if any air enters it, the oxygen is absorbed by the carbon of the organic matter; and in order that nitrification may take place there must be provided an excess of oxygen beyond that which will be readily taken up by the carbon.

The circumstances that bring most clearly to mind the essential conditions of intermittent filtration are these: a bed of gravel stones, as large as robins' eggs, having an abundance of nitrifying organisms attached to each stone, has sewage poured over it for a short time; after the sewage has settled away, every stone it has reached is covered with a thin film of liquid in contact with air and enveloping the nitrifying organisms. Then nitrification takes place rapidly and with great completeness. A single hour will make a marked change in the character of the adhering liquid.

After a few hours another charge of sewage distributed over the filter will mingle somewhat with the former adhering liquid and cause it to move downward. If this charge is too abundant, a part of it may flow too rapidly through the large interstices between the stones and reach the outlet drains without being completely nitrified. This condition limits the amount that can be purified by coarse materials. The air spaces are larger than necessary, and the area of surface is small. By decreasing the diameter of the stones to one-tenth of their present diameter, we may still have the same amount of air and water space and ten times the surface to which the water may adhere. In this case the air spaces between the films, though very much smaller than before, are sufficient to supply the oxygen necessary for nitrification if we allow sufficient time between applications for the sand to become drained. It is, however, evident that if we continue diminishing the diameter of the grains of material, we shall reach a condition in which

the films of water adhering to the grains will occupy the whole space; there is then no room for air, and nitrification cannot take place. Sand in a filter-bed that remains saturated after draining 24 hours is of little value and may be very objectionable.

Up to the present time the experiments of the State Board of Health indicate that the sand of even grain that presents all of the conditions most favorable for the very complete purification of sewage has a diameter of grain of about two-tenths of a millimeter, or about eight-thousandths of an inch.

The more even in size the grains are the better, but as we rarely find a sand in which some of the grains are not many times the size of others, and as the conditions for nitrification depend more essentially upon the finer grains of the mass, we have found it more intelligible to classify sands by the finer 10% of their grains, and in thus classifying sands we should say, that sand presents the conditions most favorable for very complete purification of sewage, the finer 10% of whose grains has diameters equal to and less, but not much less, than 0.2 mm.

In soils, the organic matter, which is much finer than this, makes up a considerable part of the finer 10% of the particles, and this, sticking to the other particles, decreases the air and water spaces to a greater extent than would appear from the mechanical analysis; hence, while a filter-bed made of soil, whose finer 10% has diameters equal to and less than $\frac{2}{100}$ mm., will be entirely ineffectual in purifying the smallest amount of sewage, one made of clean sand, whose finer 10% has diameters equal to and less than $\frac{2}{100}$ mm., may satisfactorily purify for years 30 000 galls. of sewage per acre daily.

With the kind of sand indicated above as being most favorable for very completely purifying the largest amount of sewage, the quantity that may be permanently applied to filters having a depth of 5 ft. of such sand is found to be about 100 000 galls. per acre daily.

The very complete purification here referred to produces an effluent chemically as good as many drinking waters, having in 100 000 parts about 0.0020 part of free ammonia, and about 0.0130 part of albuminoid ammonia, the former being but $\frac{1}{10}$ of 1%, and the latter but 2%, of the amount in the sewage. Nearly all of the organic matter of the sewage is burned up, forming in the effluent soluble nitrates to the extent of about 1.8 parts in 100 000. Bacteriologically, the results are

even more remarkable, there remaining in the effluent less than 1 in 10 000 of the number applied in the sewage. The appearance of the effluent is that of a bright, clear spring water.

With finer sands similar results may be obtained with decreasing quantities, one-half of the quantity being filtered by sands of whose finer 10% the maximum grains have diameters of $\frac{5}{150}$ mm., and excellent purification may be obtained with sands so fine as to allow the application of only 25 000 galls. per acre per day. In fact, with the finer sands, having a proper daily charge, the bacteria of the sewage may be more completely removed than with the sand allowing the greatest amount to be purified chemically.

With sands coarser than the most favorable size, similar results chemically have been obtained with diminished quantities, one-half the maximum quantity being filtered by sands of whose finer 10% the maximum grains have diameters of $\frac{5}{70}$ mm. Bacteriologically, these coarser sands do not give so good results, but they remove more than 99% of the applied bacteria. Sands coarser than that given as most favorable may be used for less perfect results for the full quantity of 100 000 galls. per acre per day up to the larger size just mentioned.

With still coarser sands and open gravel the quantity of sewage that may be purified for a time may be greater than the maximum amount given above, if the periods of application be made sufficiently short and sufficiently frequent; but after a time such treatment causes a thick coating of slime to form upon the surface of the grains and stones at a considerable depth, where the air is not changed rapidly enough to favor complete nitrification; hence, it is necessary to treat such coarse materials with less than the maximum amount, or else resort to drawing or forcing air through the filter, which expedient we have found capable of increasing the nitrification and allowing a much larger amount of sewage to be nitrified in coarse sand filters.

With the material best adapted to the purification of large quantities of sewage, there is a deposit of nitrogenous matter in the upper layers amounting to about 15% of all of this kind of matter applied in the sewage. The other 85% is oxidized and passes off in solution as nitrates in the effluent. The effect of this deposit on and near the surface is to decrease the air space between the grains of sand and increase the amount of water continually held by these layers; thus, in time preventing sufficient change of air in the layers beneath. Continued

efficient action may be had by frequently raking over the surface to the depth of 1 in.; but there comes a time when this upper inch should be removed and replaced by clean sand. With the full complement of 100 000 galls. per acre daily of such sewage as has been filtered at Lawrence, the upper layer 1 in. in depth should be replaced by clean sand once in about eight months. With other rates of application of sewage, about 1 000 galls. of sand should be replaced for each 1 000 000 galls. of sewage applied.

The sewage that has been used upon the filters of the Experiment Station at Lawrence is pumped from one of the main sewers above where manufacturing wastes enter, and where the sewage, coming from stores and from the homes of about 10 000 people, may be regarded as ordinary city sewage, including storm water. The sewage is drawn through a cylindrical strainer lying horizontally and diagonally across the sewer a few inches above the bottom. This strainer has many holes ¾ in. in diameter. Lying as it does between the bottom and the top of the stream of sewage, it is probable that the sewage drawn through the pipe does not contain as much of the fatty substances floating on the surface of such a stream, nor as much of the mineral matter moving over the bottom as if the sewage flowed directly from the mouth of the sewer upon the filter, but quite as much of these substances as sewage separate from storm water passed through grease traps and the settling basins usually used with sewage to be filtered.

An average analysis of the sewage put upon the filters in parts per 100 000 would be about as follows: Loss on ignition, 20 parts; fixed residue, 30 parts; free ammonia, 2 parts; albuminoid ammonia, 0.7 part, and chlorine, 6 parts. One-third of the organic matter shown by loss on ignition is in suspension. One-fifth of the mineral matter and one-half of the nitrogenous matter as shown by the albuminoid ammonia is in suspension. The average number of bacteria was 800 000 per cubic centimeter.

With sewage containing more nitrogenous matter in suspension than here given, the upper inch in depth of sand would require to be replaced more frequently than above stated, and with correspondingly less frequency if the nitrogenous matter in suspension were less.

With such sewage as above described an excellent but attainable result during warm weather is an effluent whose analysis has been

already given and is now repeated for immediate comparison. Free ammonia, 0.0020 part; albuminoid ammonia, 0.0130 part, and nitrogen as nitrates, 1.8 parts, and less than $\frac{1}{100}$ of 1% of the number of bacteria applied.

To obtain as good a result in a cold New England winter it is necessary to protect the surface of the filter-bed so that it will not freeze. If the sand freezes at the surface the sewage thaws places here and there and passes too rapidly through the sand in sections having less than the whole area of the bed; air is partially excluded and nitrification is checked. A closed shed which will keep snow and wind from the bed will be sufficient covering where the sewage used has the ordinary temperature of sewage in sewers of 45° Fahr. or more.

Unprotected beds treated with such sewage may be expected to have nitrification very much checked and an increase in organic matter in the effluent shown by the albuminoid ammonia, amounting to three times the quantity found during the warm months, with a larger multiple of the bacteria. Four such beds through the coldest months removed an average of 91% of the albuminoid ammonia of the sewage and 97% of the bacteria; but there results from the decrease in nitrification a storing of organic matter in the filter which is only partially removed in the warm months, and the permanence of the filter is somewhat impaired. If filters are to be run nearly to their full capacity, they should be protected from freezing.

Fine sand filters may have their capacity increased by excavating trenches about 5 ft. apart, 1 ft. wide and 2 ft. deep, and filling them to within 3 ins. of the top with coarser sand and applying all of the sewage to the surface of the coarse sand. In winter, boards may be put on across the trenches under which the sewage will flow and, being protected from snow, it will not freeze. Sand so fine that 15 000 galls. per acre per day exceeds its capacity may thus be enabled to filter satisfactorily 30 000 galls.

The amount of sewage that may be applied at one time depends upon the size of the grains of sand and the resulting amount of air and of water held after draining. With gravel stones which retain very little water the amount applied at once should not be as great as the amount retained, otherwise some of it will flow through immediately without sufficient time for the chemical changes to take place. On the other hand, fine sands retaining a large amount of water hold but little

air; and as sewage needs as much as its own volume of air for its oxidation, we have here the quantity that may be applied at one time limited by the quantity of air held by the filter when the sewage is applied.

The quantities that have been indicated as being very completely purified daily by the different sands, express nearly the maximum quantity that may advantageously be applied at once. Smaller quantities, with intervals of a fraction of a day, may be advantageously applied to coarse materials.

As illustrated by the filter of gravel stones, the purification of sewage by intermittent filtration is in no essential degree a straining process; it is essentially exposing the liquid for a sufficient time in thin films upon the surfaces of solid particles having nitrifying bacteria adherent, with air in contact with the films. These are the conditions most favorable for the chemical change, which consists of burning up the organic matter and producing the harmless mineral matter which we have called the nitrates. In continuous filtration these conditions do not exist, and no such purification is possible. It is equally true that the removal of bacteria from the liquid depends only incidentally upon straining; for example, upon straining sewage through filter paper, which is supposed to remove all suspended matter, the number of bacteria remaining in the effluent was 20% of the number applied, while the number leaving a filter of gravel stones 5 ft. deep was less than 1% of the number applied when filtering intermittently 80 000 galls. of sewage per acre daily.

Bacteria are killed by subjecting them to conditions on the passage through the filter unfavorable to their life. One very important condition is depriving them, for a sufficient time, of suitable food material. This is most effectually accomplished by burning up the organic matter in the process of complete nitrification; so that, in general, the conditions which produce the most complete chemical purification are those most favorable for the removal of bacteria. It also results that the effluent in which nitrification has been complete is unfitted to support the life of bacteria. On the other hand, water that has been boiled supplies a good food for bacteria, and if such water be treated with a small percentage of unboiled water, the bacteria thus introduced may increase in a few days to a thousand times the number then to be found in the unboiled water. If, when very completely nitrifying the

sewage applied to it, a filter be flooded with water from a boiler, the following effluents from sewage will contain a much larger number of bacteria than usual.

It was found that heating the sand of a filter to 300° Fahr., or more, and pouring boiling water through it caused 100 times as many bacteria to pass through it with sewage for three months as passed through a similar filter whose sand and first water had not been heated. This appears to be due to preparing the organic matter in the sand and in the water by heat, so that it is a better food for the bacteria.

When working along with steady application of ordinary sewage, with surface kept sufficiently free to allow air to enter and make nitrification satisfactory, the number of bacteria found in the effluents of 10 filters averaged $\frac{8}{100}$ of 1% of the number applied in the sewage. With filters having sands coarser than the sand which we have specified as best adapted to purify the largest amount of sewage, the number remaining in the effluents was about $\frac{2}{10}$ of 1%; while from the filters with sands finer than the standard, the number remaining in the effluents was but $\frac{1}{1000}$ of 1% of the number applied in the sewage. In fact, we have the strongest reason to conclude that with these sands no bacteria ordinarily lived through the passage, but that under peculiar circumstances a few survived, and these lived in the under-drains, and occasionally from these a few units came in the effluent to represent the hundreds of thousands applied. Sometimes the few found in the effluent were a pure culture of a single species of bacteria.

With the facts that with the coarser sands the number of bacteria that live to get through the filter, when nitrification is nearly complete, is an extremely small percentage of the number applied in the sewage, and that the effluents from highly nitrifying filters are not adapted to the support of bacteria, we have still to ask whether any disease germs will pass such filters, and if any pass, will they increase in the effluent and in a stream to which this may flow?

It has been found that most of the bacteria that get through the filters are of kinds that live and are propagated in wet sands and underdrains. If typhoid fever germs were applied with the sewage, their lateness of development upon gelatine plates allows other bacteria to grow in such numbers or to liquify the plates to such an extent that the typhoid fever germs, if present, can hardly be distinguished; hence, it becomes necessary to select a foreign species, not

found in our sewage, having habits of life similar to typhoid fever germs, that can be readily distinguished from other bacteria; such is *Bacillus prodigiosus* which has been cultivated in large numbers and applied by the millions to the several filters.

With sands whose finer 10% had grains as large as $\frac{5}{16}$ mm. we have succeeded in passing through a few of the *Bacillus prodigiosus*, and conclude that typhoid fever germs would pass through such sands in very much reduced numbers.

With sands of $\frac{3}{16}$ mm. and less we have not succeeded in finding in the effluents any of the large numbers of *Bacillus prodigiosus* applied with the sewage. These results, together with the fact that typhoid fever germs continually decrease in numbers, not only in the effluents from these filters, but even, although less rapidly, in sewage-polluted waters which have not been filtered, dying out in the latter in from one to three weeks, give us confidence in concluding that filters made with these finer sands, so long as they are kept in a condition to very completely nitrify the sewage applied, will give an effluent that may with safety be turned into a drinking-water stream.

Study of the working of intermittent filters shows them to be not mechanical strainers, but delicate organisms gradually growing fitted to perform the work required of them, needing time to adapt themselves to any marked change in the amount or quality of the organic matter applied to them, but regularly, and for many years, performing an astonishing amount of chemical and biological purification, if the essential conditions for their action are maintained.

As previously stated, the sewage pumped from the Lawrence sewer does not to any large extent contain wastes from manufactories and dye works. Sewage highly colored at the Station with the ordinary coloring matters used in dye works was applied intermittently for weeks to several filters with the resulting effluent entirely colorless.

Acid sewage, applied occasionally, does not interrupt nitrification, but if long continued, with sand containing no alkali, it causes nitrification to cease. This may be prevented and nitrification continued indefinitely if in constructing the filter thin layers of granulated limestone, having grains about the size of the sand grains, are built into the upper part of the filter.

Soap applied in large quantities may clog the upper layers of a filter and prevent nitrification, in which case the upper layers should be replaced by clean sand.

Filtration of Water.—The principles of the purification of sewage by intermittent filtration are applicable to the purification of polluted water supplies, with this important difference: water supplies have not sufficient organic matter to combine readily with all of the oxygen the water absorbs from the air, consequently they contain more or less free oxygen; hence, they do not require so frequent renewal of air in the sand, and much larger quantities can be passed through the filter and find there a sufficient additional amount of air to combine with what nitrogenous matter they contain, to nitrify it through longer periods of continuous use than the still more polluted water which we call sewage.

We may in a very general way distinguish between the two by saying sewage contains 50 times as much nitrogenous organic matter as a polluted water supply. The question may then arise, can we satisfactorily purify by filtration 50 times as much water as sewage upon the same area? It may prove to be practicable in the future, but at present we will give attention to results that have been obtained when filtering about half of this amount.

One of the first steps in considering what sand to use in a filter is to determine how much water will flow through it with the available head. Mr. Allen Hazen, the chemist in charge of the Experiment Station, found the quantity that would flow through the sands ordinarily used for filtration* to be, at a constant temperature, directly proportional to the acting head, and inversely proportional to the

* Mr. Hazen also made a few experiments to aid in determining the amount of coarse material necessary for underdraining the sand, which may be summarized as follows:

QUANTITY OF WATER FLOWING THROUGH GRAVEL STONES AT DIFFERENT HEADS.

Loss of head in terms of distance through gravel.	Size of gravel stones in millimeters and inches. The finer 10% finer than—							
Millimeters	3	5	8	10	20	30	40	50
Inches.....	0.12	0.20	0.32	0.39	0.79	1.2	1.6	2.0
	Quantity flowing in 1 000 000 gallons per acre daily.							
0.0005	4	12	22	35	90	170	280	410
0.001	7	23	43	65	160	300	480	690
0.002	15	43	84	120	300	490	720	1 040
0.004	29	83	160	230	520	790	1 070	1 360
0.01	72	185	320	420	890	1 280	1 670	2 150
0.02	136	320	500	630	1 280	1 800	2 340	3 030
0.05	300	600	950	1 140	2 030	2 862	3 734	4 800
0.10	530	1 000	1 400	1 650	2 850	4 044	5 280	6 800

depth or distance through the sand. He also found it directly proportional to the square of the maximum diameter of the finer 10% of the sand grains. Calling the maximum diameter in millimeters d, the head in feet h, the distance flowing through the sand l, and the quantity in 1 000 000 galls. per acre per day Q, he found the following formula to satisfactorily express the results of his experiments with water at about 50° Fahr.:

$$Q = \frac{800\ h\ d^2}{l}.$$

The sand which we have found capable of very completely purifying the largest quantity of sewage having d equal to $\frac{2}{10}$ mm. would, when 1 ft. deep and with 1 ft. acting head, allow 32 000 000 galls. per acre to flow through it in 24 hours; and the same quantity would flow through any other depth if the acting head were equal to the depth. There are practical considerations that make it desirable to depend upon a less head than the distance the water passes through the sand. If there be 1 ft. acting head for a passage of 5 ft. through the sand, the maximum quantity that would flow through this sand in 24 hours would be 6 400 000 galls. per acre; but the whole 24 hours would not be available if the water be applied intermittently. With the Merrimac River water used in the experiments it was found that filling the sand with air once a day was sufficient; in which case we can count upon a steady flow through the sand for two-thirds of the 24 hours, thus passing 4 300 000 galls. per acre per day when the sand is clean; but this quantity would be still further reduced, for the water has some organic matter and some mineral matter in suspension at all times, and during the spring freshets the amount of mineral matter is very large. All of this suspended matter tends to clog the interstices of the upper layer of the filter and to allow less water to pass; hence, the sand of the filter must be coarse enough to allow the desired quantity to flow through when the upper layer is obstructed, and not make the intervals between scrapings of the surface to remove this deposit too inconveniently short.

With the water used, the sand we are considering allowed 60 000 000 galls. of water to pass through 1 acre between the times when it was necessary to scrape the surface and remove about $\frac{1}{8}$ in. of sand and sediment and replace with clean sand.

When filtering 2 000 000 galls. per acre daily, the deposit had to be

removed once a month in the six months from May to October, and more frequently during the spring and fall freshets. With coarser and finer sand the amount passed between scrapings was nearly in proportion to the size of the sand grains.

Sands, the larger grains of the finer 10% of which are from $\frac{1}{10}$ to $\frac{3}{10}$ mm. in diameter, and whose capacity to pass water through a depth equal to the acting head ranges from 8 000 000 to 72 000 000 galls. per acre in 24 hours, have given excellent results when filtering 2 000 000 galls. per acre per day, and the mean of these sizes has also satisfactorily purified 3 000 000 galls. per acre per day.

With still coarser sands, up to $\frac{5}{10}$ mm. in diameter, good results have been obtained when filtering 1 000 000 galls. a day; but the results were variable, and the largest size mentioned has not given assurance that sewage polluted water can be constantly purified from its disease germs.

With filters having 5 ft. in depth of sand, whose finer 10% had maximum grains from $\frac{1}{10}$ to $\frac{2}{10}$ mm. in diameter, the chemical purification, when filtering at the rate of 1 250 000 to 2 000 000 galls. in 24 hours, was very satisfactory, both with continuous and with intermittent filtration. The following are average results in parts per 100 000 :

	Free ammonia.	Albuminoid ammonia.	Nitrogen as nitrates.
Unfiltered water from the river	0.0070	0.0187	0.0119
River water filtered continuously	0.0008	0.0078	0.0251
River water filtered intermittently	0.0007	0.0075	0.0468

As before indicated, there is in drinking water nearly enough absorbed oxygen to combine with the nitrogenous organic matter to burn it up or to nitrify it, when it is brought in contact with nitrifying bacteria under conditions favorable for their action. Filling the sand with air once a day furnishes the additional quantity of oxygen necessary for very complete nitrification.

In the results just given we find in continuous filtration the free ammonia is reduced from 0.0070 to 0.0008 part, or to 11% of the original; the albuminoid ammonia is reduced from 0.0187 to 0.0078 part, or to 42%, while the nitrates are more than doubled. In intermittent filtration the free and albuminoid ammonias are reduced to 10% and 40%, respectively, and the nitrates are quadrupled. The large additional amount of the nitrogen which has come through the intermittent filter as soluble nitrates has remained in the continuous

filter and often gives rise there to growths of organic matter which are objectionable.

Similar chemical results may be obtained with filters having sand 4ft. deep. With less depths the purification is less complete, but even with a depth of only 1 ft. of sand the free and albuminoid ammonia were reduced to 21% and 52%, respectively, of the unfiltered water, and the nitrates were nearly doubled; still, these shallow depths cannot be depended upon to give constantly reliable results.

While the chemical change that takes place in the water when passing through the filter is important, it is much less important than the removal of bacteria. One very important effect of burning up the organic matter and forming nitrates, is removing the food supply that would support the life of injurious bacteria. It is probably fair to state that the invisible vegetable kingdom of bacteria is as a whole no more injurious to man than the whole of the visible vegetable kingdom. As in the latter, there are certain poisonous plants, so in the former there are a few species that cause disease in man. Of these we know but little, but as far as studied we do not find that they increase in sewage polluted water. The temperature and food supply they find in the human body are better adapted to their propagation, and while they continue for a time to exist when turned with sewage into a stream or pond, it is probable that they continually decrease in numbers.

The longest time we have been able to keep the germs of typhoid fever alive in Merrimac River water is about three weeks; more commonly they disappear in one week. This short period of existence of typhoid fever germs in such waters presents the probable reason why typhoid fever may be readily carried down a river from city to city using the water for drinking, while a polluted stream may enter one end of a large pond whose waters are changed only after months, and a water supply drawn from the opposite end may be continually free from the disease pollution. It is also a reason why we may be satisfied in removing nearly all, if not quite all, of the disease germs from a polluted water by filtration.

As there are found to be certain species of water bacteria that grow and increase in numbers in wet sand and in the under drains of filters, the efficiency of filters in removing disease germs must be determined by applying to them water inoculated with a known number of these

germs or with others having similar conditions of life, and learning how many, if any such, remain in the effluent.

Most of the tests which the State Board of Health relies upon as giving the efficiency of different filters in removing disease germs, have been made by applying to the filters water containing large numbers of the typhoid bacillus or of the more easily recognized *Bacillus prodigiosus*.

These tests show that with sands whose finer 10% have grains equal to or less than from $\frac{1}{10}$ to $\frac{2}{10}$ mm. from 1 500 000 to 3 000 000 galls. of water containing large numbers of these germs may be filtered daily upon an acre with the constant removal of more than 99½% of the germs, and it is probable that a similar result would attend the use of sand up to a diameter of $\frac{3}{10}$ mm.

It is found that after scraping the surface of the filter, a few more germs are found in the effluent than before, but the number removed at this time is still more than 99½% of those applied.

With the intelligent care and favorable conditions at the Experiment Station less than ½ of 1% of the applied germs live to get through the water filters, with sands varying in depth from 1 ft. to 5 ft.; and, within this limit, the deeper filters and the finer sands allow smaller numbers to pass.

The difference in the efficiency of removing these applied germs with sand 1 ft. deep, or with sand 5 ft. deep, is so small that it is evident that nearly all of the removal is effected by the upper foot of material. In fact, in a filter having 1 ft. in depth of sand which had been filtering continuously for six months the surfaced was scraped, and in the next ten days more than 2 000 million of *Bacillus prodigiosus* were applied from day to day. The sand was then carefully examined and found to contain 13% of the number applied, 93% of which were found in the upper ¼ in. None were found alive below the upper inch. This was not the case with the ordinary river bacteria; they were distributed throughout the sand, but with greatly decreased numbers below the upper inch.

With intermittent filtration of water, the number of germs remaining alive in the sand is very much less than with continuous filtration. Some examinations in the summer have shown the number in the upper ¼ in. to be but 1% of the number that had been applied. The ordinary river bacteria do not survive within the sand in intermittent filtration to nearly the same extent as in continuous filtration.

Long series of experiments with the filters which we regard as adapted to the filtration of water supplies have shown, immediately after, as well as before, scraping the surface, a removal of more than $99\frac{5}{10}\%$ of the applied germs, and if all of the disease germs like those of typhoid fever do not increase, but rapidly decrease, in filtered water, we may conclude that the $\frac{5}{10}$ of 1% of the number applied will do little or no harm.

Such results can only be obtained in actual practice by having the filters constructed with the most intelligent care, having in view particularly that the sand shall be so placed that it forms a homogeneous mass without stratification or coarse-grained channels down through which an undue quantity of water may flow ; and when in use the surface should be as intelligently kept in order so that every square foot shall continually do its allotted part of the work.

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THE SEWERAGE SYSTEM OF MILWAUKEE AND THE MILWAUKEE RIVER FLUSHING WORKS.

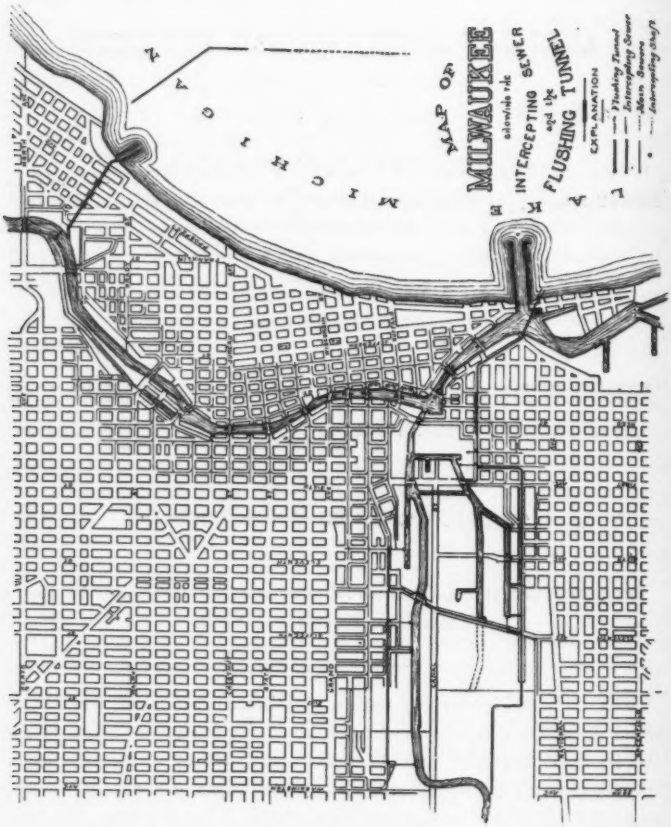
By G. H. BENZENBERG, M. Am. Soc. C. E.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

The city of Milwaukee, with a population of about 240 000, is situated on the west shore of Lake Michigan about 100 miles below the head of the lake and 86 miles north of the city of Chicago. Its area is 21 sq. miles, having a length of 6½ miles north and south along the lake front, with a maximum width of 4½ miles from the lake shore. It is divided into four natural divisions by three rivers converging into one common outlet about midway between the north and south limits. The natural outlet of these rivers was originally ½ mile further south, but, in order to improve the harbor, the city in 1854 constructed the present outlet, which since that time has been ex-

NOTE.—Discussions on all papers presented to the International Engineering Congress will be published simultaneously in the number for December, 1893.

tended and maintained by the Government as the harbor entrance, the old outlet meanwhile having been closed by the sand accretions and the action of the waves.



By enactment the city is divided into three divisions. The east division, having an area of $3\frac{1}{2}$ sq. miles, is situated between the lake and the Milwaukee River, which flows from the north, nearly parallel to the lake shore and from $\frac{1}{4}$ to 1 mile distant therefrom; the west division, with an area of $9\frac{1}{2}$ sq. miles, is situated west of the Milwaukee and north of the Menomonee River, which flows from the west and

joins the Milwaukee River about ¼ mile west from its outlet; the south division, with an area of 7¾ sq. miles, is situated south of the harbor and the Menomonee River, and lies on both sides of the Kinnickinnic River, which is the smaller of these streams and flows from the southwest emptying into the Milwaukee River at its present outlet. The lower east and west divisions became first settled, and form to-day, for a distance of ½ mile north of their southern boundary, the center of the business section as well as of the population of the city. Near the mouth of the rivers, which are each navigable and docked for a distance of about 2½ miles, the territory was originally covered by a large marsh which now forms the low level district, and from which point the ground gradually ascends, the river banks becoming steeper in proportion to their distance from their outlets until the ground finally reaches an elevation of from 100 to 140 ft. above the lake level. The various earlier manufactories were originally located along the banks of the Milwaukee River, but have since, with the exception of the tanneries, been removed to the Menomonee and Kinnickinnic valleys, which, on account of their greater width, have become the great railroad yards and their outlets. The natural flow in these rivers is, excepting in the spring or at the time of a long, severe rain storm, very small, at times in the summer ceasing altogether. The flow over the dam across the Milwaukee River, originally constructed 3½ miles above the harbor entrance for canal and power purposes, averages during the summer months not over 15 000 000 galls. per day, notwithstanding the watershed of this river covers an area of 675 sq. miles. Hence, the current in these streams is naturally very sluggish, and, on account of the winds on the lake, nearly as often up stream as down stream.

In 1869, when the population had reached 68 000, a general sewerage system, designed by the late Mr. E. L. Chesbrough, M. Am. Soc. C. E., was adopted, and the construction of sewers according to such system commenced on a large scale. This system, which covered a territory of 4¾ sq. miles in the heart of the city, contemplated the removal of all storm water as well as sewage, and provided for the discharging of the same into the streams at the banks of the rivers. The plan of this system has since been extended and added to until now it covers the entire present area of the city. There have been constructed 226.41 miles of sewers, at a total aggregate cost of $2 888 977.71.

Forty-seven or 63% of these sewer outlets, varying from 18 to 96

ins. in diameter, are located along the Milwaukee River, and drain 40% of the above area into it. Forty-two per cent. of the area is drained through 17 sewers into the Menomonee valley, in addition to which the stream and canals in said valley also receive the refuse of all the large packing-houses, distilleries and other like establishments located along their banks.

In 1872 the construction of the water-works of the city, designed by the late Moses Lane, M. Am. Soc. C. E., was commenced. These have been extended, until now the total cost of the works has reached the sum of $4 013 994.46, and the distribution system covers a total length of 229.14 miles of water mains. The introduction of the water-works naturally hastened the extension of the sewerage system. The result of the discharge of the sewage and factory refuse into the sluggish streams soon became noticeable, so much so, that within 10 years after the adoption of the system, the offensiveness of the rivers and canals in the Milwaukee and Menomonee valleys became a matter of public agitation and earnest complaint. Intercepting sewers along the banks of all the rivers were generally suggested as the proper remedy. To determine the best method of abating the ever-increasing nuisance, and to insure the purity of the water supply, the solution thereof was entrusted to an engineering commission, consisting of Messrs. E. S. Chesbrough, Moses Lane and George E. Waring, Jr., who in 1880 recommended the purchase of 500 acres of land whereupon in the future to dispose the sewage by irrigation. They also recommended the construction of a series of low-level intercepting sewers, the contents of which were to be pumped out into the lake 1 mile south of the harbor entrance, as well as the construction of self-acting flush tanks at the heads of the sewers.

As a result of these recommendations, a plan providing for the construction of an intercepting sewer from the lake shore immediately south of the harbor, westward and to the south of the Milwaukee and Menomonee Rivers to the center of the large packing-house district, was adopted; and in 1881 the east 4 300 ft. of this sewer, being from the west bank of the Milwaukee River westward, was put under construction. Succeeding to his present office in 1882, the writer believed that to even partially restore the waters of the Menomonee valley to their former condition would require, not only the collection of the refuse of the factories, but the intercepting of all the sewers of the

system emptying thereinto, and principally the creation of a flow in the terminal canals and in the sluggish stream itself by artificial means, by the constant introduction of a body of purer water to assist in the purification by dilution. Hence, the size and grade of the unfinished part of this intercepting sewer, as well as its location, was changed, so as to keep it entirely below the surface of the canals, by extending it so as to reach every sewer outlet on each side of said valley. The amended plan provided for submerged connections with the upper end of each terminal canal, and also at intermediate points, so that by using the excess capacity of the intercepting sewers to remove the stagnation of the canals, purer water would follow, which again would aid in diluting the crude sewage in the sewer on its way to the lake, thus constantly increasing the dilution and assisting Nature in the performance of its restorative functions. This natural, healthy and universal process of purification of all decaying matter is continuously and uninterruptedly going on everywhere in life, either in the air, water or in the earth, so long as stagnation is not permitted to clog the process, and the healthy life germs, whatever form they may take, predominate in sufficient proportions. Herein undoubtedly lies the solution for the abatement of all nuisances from whatever source they may originate, or for the destruction of all disease germs. Nature has amply provided for the performance of this function everywhere, excepting where man has interfered therewith by accumulation or by a neglect of natural laws. To avoid and escape the results which quickly follow and augment upon such interference, man must assist in restoring such natural process, and, if caused by accumulation, must, by a proper redistribution or dilution, sufficiently re-establish the conditions necessary to the resumption of the process of purification; generally this may be successfully accomplished by artificial means, providing the proper conditions are maintained. Wherever the artificial process of purification has failed, it has generally been due to the fact of not understanding or of not maintaining the proper distribution of decaying matter, either in irrigation, filtration or dilution, or in not following the laws of Nature.

With this apparent fact in view, the uncompleted part of the intercepting sewer for the Menomonee valley was enlarged generally to the dimensions of the completed part, which was of 5 ft. 4 ins. internal diameter, although 7 ft. diameter would have been a more suitable size, and

in accordance with this amended plan the work has been completed. The first section of this sewer was constructed almost entirely of 8-in. timber beveled, to assume the cylindrical form; all subsequent work, however, was constructed of brick. There are two river crossings consisting of wrought-iron inverted siphons. The first, near the outlet, carrying the sewage across the Milwaukee River to the pump well, was laid in 1884, is 50 ins. in diameter and 520 ft. in length, and laid 26½ ft. below the river surface, connecting steel and brick-lined shafts on each side of the river. The second was laid in 1888, and crosses the North Menomonee Channel at a depth of 24 ft. below the water surface; is 40 ins. in diameter and 200 ft. in length. This siphon has unequal ascending arms, forms several slight angles in its crossing so as to avoid a bridge pier, and at its upper end has a submerged connection with the channel, for the purpose of flushing out the siphon and overcoming the stagnation of said channel.

Ninety miles of sewers now discharge their sewage into this interceptor through 12 connections. These connections are so constructed as to permit the dry weather flow, or sewage proper, to flow through an opening into the intercepting sewer below, over which the storm water is carried towards the outlet of the sewer into the streams by virtue of the increase of velocity due to such increased volume. This style of connection, which needs no attention or mechanism to regulate the flow of the sewage, can be easily constructed to perform its duty accurately. Plate I shows a section of the first of these connections, constructed in 1887, which has required no attention since, though it has been frequently examined as to its operation.

The submerged connections with the canals are each controlled by a valve, so as to regulate the flow from these canals, both as to volume and location, always utilizing the intercepting sewer to its greatest capacity by keeping the water in the pump well at the lowest possible level at which the pump will take suction. The pump, which is of the centrifugal type, is located on the narrow neck of land south of the harbor, and is situated between the lake and the Milwaukee River. Plate II, which is a sectional view on an east and west line, shows the pump well, pump, engine and discharge into the lake. The average lift during the low-lake level for the past six years has been 15 ft., with an average discharge of about 39 000 galls. per minute.

This pumping engine, which was designed by Mr. Edwin Reynolds

and built by the E. P. Allis Company, of Milwaukee, has a capacity of 70 000 000 U. S. galls. per 24 hours, with a lift of 18 ft., and is a horizontal tandem compound engine with a 24-in. diameter high-pressure and a 43-in. diameter low-pressure cylinder and 48-in. stroke. The cylinders are steam-jacketed and fitted with Reynolds-Corliss valve gear. The main shaft of the engine is vertical, having the pump attached to the lower end, with the crank and fly-wheel moving in a horizontal plane. The pump disc is 12 ft. in diameter, with openings between the blades of sufficient size to pass readily ordinary-sized objects contained in sewage, and moves at a speed of from 65 to 70 revolutions per minute. The sewage is sucked from below and discharged from the rim of the pump disc through a circular casing into a 6-ft. diameter brick conduit, discharging over a weir into the lake. The suction well is provided with a gate, so that any part of the pump may be reached. Steam is supplied, at a pressure of 55 lbs., from three horizontal tubular boilers, each 60 ins. diameter by 16 ft. long, containing 54 4-in. tubes, with an additional boiler always in reserve.

This pump was started on August 1st, 1885, and has been operated continuously since, with the exception of a few weeks each spring, when it has undergone a thorough examination. The average annual duty developed by it has never been below 58 000 000 foot-pounds per 100 lbs. of coal consumed in the boiler furnaces, without any deductions of any kind, even for the heating or electric lighting.

The 56 000 000 galls. pumped each day, of which about 18% is sewage and refuse from packing-houses and other establishments in the valley which are all directly connected with this sewer, and the other 82% of which is river water, are discharged with considerable velocity out into the lake. With the exception of a very few days in the year, this discharge is carried off to the south with the lake current, which along the west shore of the lake is uniformly to the south, unless counteracted on the surface by a strong south wind or interfered with by a severe storm on the lake. The line of sewage current is well defined by its dark-brown color, which gradually, however, becomes lighter towards South Point, and at a distance of 6 miles from the works entirely disappears.

The result in the valley has been that, naturally, the discharge of sewage and offensive refuse into the canals and stream in the Menomonee valley, within the city limits, has ceased. This in itself, however,

did not improve matters in these canals, for although much dredging was done from year to year, yet the almost liquid sludge, which had accumulated for over 20 years, largely remained on the bottom, and merely required the raising of the temperature of the nearly stagnant water during the summer season to cause the development of gases, which, being absorbed by the water to saturation, and coloring it nearly black, then became perceptible and very offensive. By utilizing the excess capacity of the intercepting sewer in drawing water out of the upper ends of these canals, particularly since a supply of clearer cold lake water in the Milwaukee River through the flushing works has been brought to the mouth of the Menomonee valley, a gradual change is brought about. The water drawn out of each canal is replaced by cooler, clearer water, which checks the formation of gases, creates a slight current, and dilutes the sewage until the same becomes clear or nearly so; and the canal waters that formerly were in hot weather a living mass of putrefaction became clear and clean enough to be used in steam boilers and to induce people to bathe therein. The excess capacity of the sewer, however, not being large enough to permit the drawing of the water from all the canals simultaneously, the connections are opened successively, as the conditions require. All the canals are thus kept in a very fair and good condition, excepting, however, the westerly end of the north canal, which receives the waters of the river from beyond the city limits, where they are polluted by the sewage and factory discharge of numerous institutions along its banks.

While this work in the Menomonee valley was being gradually extended as rapidly as the funds would permit, the Milwaukee River gradually became more and more offensive, until, in 1887, it was perhaps as black, foul and offensive as any stream in the country. As a relief, intercepting sewers along each bank of the river were generally demanded, notwithstanding the finances of the city and the constitutional bond limitation made it practically impossible to carry out such thorough and permanent work, excepting through a long number of years, and without any possibility of relief until the entire work was completed. In December, 1887, a commission of engineers, consisting of T. J. Whitman, J. P. Davis and Henry Flad, Members of the American Society of Civil Engineers, was appointed to assist in devising plans, with estimates of costs, for the construction of works for the

collection and final disposal of the sewage of the city and for the supply of a sufficient quantity of pure water for the city. This commission submitted its most complete and comprehensive report on May 21st, 1889.

Believing, however, that a speedy and prompt relief had become absolutely necessary, the writer recommended the construction of a large tunnel from the lake to the river at a point just below the dam, and the forcing of a volume of water through such tunnel sufficient to displace the entire volume of water in the river from the dam to its mouth each 24 hours, thus insuring a dilution of the sewage discharged into the river through 47 different sewers, sufficient to promote the natural process of purification, and to prevent the fouling of the waters or the formation of gases from the sludge on the bottom, and also to assist the work of improving the canals in the Menomonee valley. Notwithstanding a continuous and general opposition by almost every citizen and paper in the city, this work was finally authorized. It was contracted for December 8th, 1887, and completed sufficiently to allow the first flow of water to be forced through the tunnel into the river on the 14th day of September following, or within less than nine months after it was started.

The sewage and factory liquids emptied into the Milwaukee River were estimated at about 10 000 000 to 13 000 000 galls. daily, which, together with the gases continuously bubbling up from the river bottom during warm weather, did not take long each spring, and again within few days after each heavy rain, to make the sluggish stream a detestable nuisance. Finding, upon examination, a deposit of from 18 to 24 ins. of semi-liquid sludge all along the bottom of the river, and reproducing by experiment on a small scale the formation of gases from some of this sludge and their result upon the water, and ascertaining that a temperature of 69 to 71° was necessary to their development and that a dilution of the sewage with 25 to 30 times its volume of clear water was sufficient to prevent it from becoming noticeable, that proportion of clear, cold lake water to the sewage discharge was determined upon as the amount necessary to produce a speedy and prompt abatement of the river nuisance. The shortest distance from the lake shore to the river immediately below the dam being about 2 500 ft., and not desiring to produce a head of more than about 2 ft., the diameter of the tunnel was fixed at 12 ft., and the line located from

a point on the lake shore within and near the upper end of the harbor of refuge where the sand accretions had formed a beach, to a point within 200 ft. of the Milwaukee River just below the dam. From this point the tunnel was curved so as to approach a line more nearly parallel to the river, with the view of discharging the water into the stream at an angle that would not tend to retard unnecessarily the velocity of flow. The grade of the tunnel was made level and at such depth that the crown would be 2 ft. below city datum or supposed low water. At the lake end under the sand beach, another curve was made in the tunnel, to permit the placing of the pumping engine outside, but in direct line of the main tunnel, and to enable the taking of the supply from the harbor in a southerly and protected direction. A 12-ft. diameter wedge gate was placed in the tunnel each side of the pump chamber, and another having in its center a 3-ft. diameter auxiliary gate was placed near the outlet at the river, so as to permit the pumping out at any time of either the tunnel or pump chamber. The tunnel is a circle in section and encased with four rings or 18 ins. of brickwork. The outlet is constructed of stone through an offset in the dock having its face down stream. The inlet consists of two parallel piers made of a single row of piles 4 ft. apart between centers, backed on the outside with a double row of 3-in. pine sheath planking screw-bolted to a 12-in. cap timber fastened to the top of the piles. These piers extend out for a distance of 610 ft. from the beach into 10 ft. depth of water, and are placed 110 ft. apart, so as to reduce the velocity of the current between them, and toward the pump, sufficiently to prevent the moving of sand on the bottom of this channel, which was dredged to a uniform depth of 9 ft. Across the inner end of this channel near the beach line, a timber step resting upon piles and 2 ft. above the bottom of this channel was constructed as a further barrier against any moving sand entering the tunnel. This step also supports the 1-in. round iron bar grating across the channel, and forms the covered inlet proper, which is 65 ft. in width and converges in a distance of 26 ft. to a section of 14 ft. in width and 9 ft. in height. This section is retained for a distance of 130 ft., where it assumes a circular form and connects with the brick tunnel 10 ft. from the first gate. The rectangular conduit is constructed of timber and piling lined on all interior sides with 2 and 3-in. matched flooring. The screw pumping engine, which was designed by Mr. Edwin Reynolds to

meet the requirements of the specifications, was built by the E. P. Allis Company, and stands within a wrought-iron caisson 16½ x 26 ft. area, and 11½ ft. below city datum, on a concrete and solid stone foundation 8 ft. in depth, with the wheel shaft in direct line with the center of the main tunnel, driving the pump wheel at its end, as shown on the section on Plate III.

The engine is of the vertical steeple compound type with the high-pressure cylinder 19 ins., and the low pressure cylinder 38 ins. in diameter with a 48-in. stroke. The cylinders are steam-jacketed, the cylinder heads forming the valve chests, thus jacketing them with steam at the initial pressure for each cylinder. They are fitted with the Reynolds-Corliss valve gear with adjustable cut-offs for each cylinder. The shaft is provided with a water stuffing-box, and is fitted with a thrust-bearing and out-board bearing not unlike those of marine engines. The pump wheel is 14 ft. in diameter (the tunnel being enlarged at this point) with a cone-shaped hub 6 ft. in diameter. The wheel is a true screw and has a pitch of 8 ft. Beyond the wheel is the out-board bearing, this being supported by radial arms which are utilized as guide blades for converting the rotary motion imparted by the wheel to the water into a motion parallel to the axis of the tunnel.

Steam is supplied at a pressure of 100 lbs. by three horizontal tubular boilers, with one boiler in reserve. They are each 54 ins. in diameter by 16 ft. long, and contain 34 4-in. tubes. The engine and boilers are housed in a neat brick building. Annexed to the main building is a brick coal shed and tool room and a circular brick smoke-stack of 126 ft. in height, having an interior diameter of 4 ft. 4 ins. throughout.

The work on the tunnel was commenced on December 20th, and proceeded with fair speed at an average depth of about 95 ft. beneath the surface, partly under the center of a street and partly beneath private grounds and residences. It passed generally through a clay and hard-pan formation, with the exception of about 600 ft. in length where it penetrated a body of running sand and quicksand, and where progress was necessarily quite difficult and slow.

The work was divided into six contracts, viz.: the outlet, tunnel, inlet, pumping engine and boilers, foundations therefor and the buildings; and was prosecuted with such energy as to complete the entire

work, with the exception of the buildings, so as to permit its being operated within less than nine months from the day work was commenced. The tunnel was filled about noon of September 14th, and the machinery started. Up to the last moment the general opposition to the work had continued, and failure was predicted; but although the current in the river at the time of the starting of the pump happened to be slightly up stream, and its waters black, warm and foul, yet within 14 minutes the current in the river was reversed, and the clear, colder lake water seemed to push out the warm water in an almost solid body. Observations of the temperature of the water taken daily at a depth of 5 and 10 ft. below the surface and at the bottom of the river, at State Street, East Water Street and the Menomonee Bridges, from June 20th on through the season, showed that at East Water Street Bridge, the one nearest to the harbor, the water was from 1 to 1½° warmer at the 5-ft. depth than it was nearer the bottom, while at the other bridges there was no difference at any depth, and also that the water at the upper bridges was uniformly from 1½ to 2° warmer than it was at East Water Street. These observations were taken between 8 and 9.30 A. M. each day, and the average temperature at State Street Bridge for the month of June was 73.6°; for July, 73.4°; for August, 72.1°, and for the first half of September, 69.6°, the maximum being 76½° and the minimum 67°, the temperature of the water exceeding that of the air from 6 to 9° at that time of the morning, during the months above mentioned, in all but two instances. The color of the water was generally black and the odor very strong and offensive. Within 20 hours after starting the pump, the river assumed a color and transparency it had not known for many years, and the temperature of the water dropped on the following day to 60° and on the next days, respectively, to 58, 55, 52 and 47°, the average for the latter half of September being 53.9°. At the bridge across the Menomonee River a similar change was observed, excepting that the temperature was 2° higher, consequently the canals in the Menomonee valley were also being directly benefited, in having the supply of cold and clearer water brought at least 1 mile nearer, and without having first to overcome the natural flow from the Milwaukee River. Fermentation or the forming of gases along the river bottoms was at once checked and permanently stopped, excepting within a slip alongside of the upper Milwaukee River which received the discharge from two large sewers

and from a number of tanneries and large breweries, but which slip is since being flushed out by water drawn from the river above the dam. The condition of the river improved continuously until at times the water has been as clear, blue and transparent as in midlake, fish have again made their appearance, and fishing near the upper end has become a regular pastime.

The entire cost of this work, including right of way, etc., has not exceeded $223 000, or less than one year's interest of the cost of a complete intercepting sewerage system, while the entire annual operating expenses have never exceeded $25 000.

The result of this work has been most satisfactory in completely abating the Milwaukee River nuisance. The dilution of the sewage is so great that where the river water, discharged through its natural outlet into the lake, was formerly distinctly noticeable for many miles, and sharply defined from the lake water by its color and odor, now, excepting in times of the clay-colored flood water, no very great difference in color is perceptible. The same is true, although to a much less degree, with the effluent from the sewage pumping works, which, as heretofore stated, takes its course to the south. The new water works intake, now under construction, will, when completed, bring in the supply from a depth of 60 ft. in the lake at a point 1½ miles further out than the present intake, and still further remove all probability of even a chance contamination of the water supply from this source for a great many years to come, excepting as such may occur from some other source.

The pumping engine which has been and is performing its work with marvelous ease has never given even the least trouble. It runs continuously from some time in April, when the works are started, to the end of the year, when they are shut down for the winter, and develops constantly throughout the year a duty in excess of the 70 000 000 foot-pounds which were required by the specifications. Within six weeks after the pump was started, a series of tests was commenced to determine the volume of water which the pump was forcing through the tunnel.

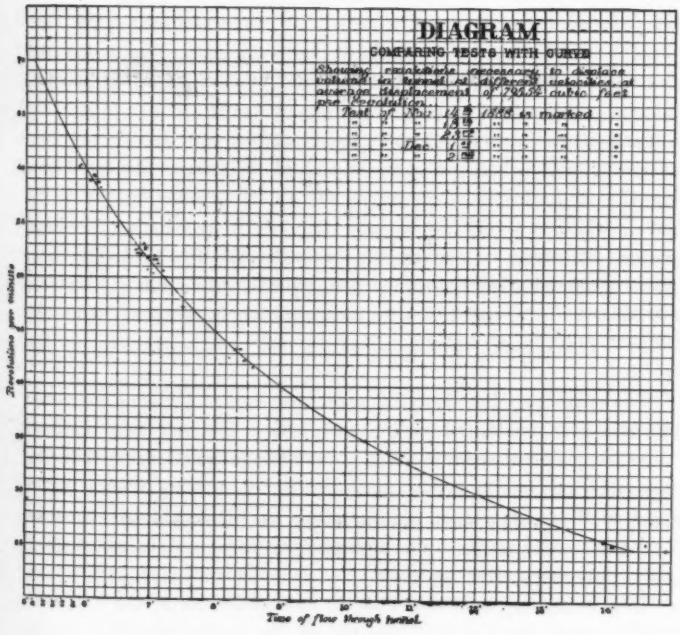
The outlet of the tunnel being entirely submerged, it became impossible to determine with any accuracy the velocity of flow in it by floats of any specific gravity. Either they would not become immediately visible at the outlet, or, if they did, they had been retarded

by contact with the arch, which facts became quite noticeable when a large number of different floats were used at one time. Eosine as a coloring matter was therefore used. There being a shaft over the center of the tunnel 5 ft. beyond the wheel, 2 ounces of red eosine, dissolved in 1 quart of water, was suddenly discharged at the center of the tunnel in this shaft and the time between its discharge and its appearance at the outlet noted, and the exact distance between the two points being known, the velocity was easily arrived at. The color was readily perceptible at the outlet, and was never distributed over a length of more than 7 to 9 ft., being about $\frac{1}{3}$ of 1% of the length of the tunnel, the center of which was taken as the point observed. The compactness of the coloring matter showed that the velocity was practically uniform at all points in the cross-section of the tunnel, which again in itself was very uniform throughout the entire length of the tunnel, as was shown from measurements taken at the time of its construction, immediately after its completion, and again in the following spring before the works were started, when the tunnel was emptied for the purpose of examination. The bricks which had been used for the interior were quite smooth, the joints were generally quite well pointed, and there were no obstructions to the flow, excepting a 4 x 6-in. block 18 ins. long, which had been overlooked and was found spiked to the brickwork at about the springing line. The first sets of observations were made with watches at each end, which had been carefully compared immediately before and after the tests, and by changing the observers so as to eliminate any difference due to personal error in observations, which in some cases was found to amount to from 2 to 5 seconds. The readings of the engine-counter were also noted immediately before and after each observation, in order to determine the average number of revolutions per minute during the time of each test, and also the total number of revolutions during such tests, or, in other words, the number of revolutions it required to displace the total volume of the tunnel between the points of observation. This total volume, being known, gave the average volume of water displaced per each revolution during such test. During the tests taken in this manner, which covered several days, the speed of the engine was varied for each double set of observations from 25 to 58.4 revolutions per minute.

In order to insure greater accuracy in these observations a telegraph

line with a key and bell at each end was run between the two points, and both observations of each test noted at each end of the line by stop watches, which were started the instant of the discharge of the eosine and stopped the instant of its appearance at the outlet. These observations of time taken at each end showed very little variation.

On December 1st and 2d, 1888, the 24-hour official duty and capacity test was made, during which time nine complete observations as to velocity of flow were made. There being another shaft over the center of the tunnel within 30 ft. of the outlet, the height of water in each of these shafts was very carefully noted at the beginning and close of each separate velocity test. The data of this trial run are hereto attached; also, the results of the velocity observations.



After the completion of the 24-hour run, during which time the speed of the engine did not at any time vary over 3%, the speed was increased to over 59, and then again reduced to about 25, revolutions

per minute, velocity tests being again made at the different intermediate speeds, the results clearly showing that each revolution of the wheel represents a displacement of 795.05 cu. ft., irrespective almost of what the speed or the head pumped against might be.

The fact is also clearly shown by the diagram, Fig. 2, showing in the curve the uniform average displacement of 795.54 cu .ft. for any speed from 25 to 60 revolutions per minute, and the observations of each day of the average revolutions and time of flow through the tunnel plotted thereon.

The data of December 1st and 2d are, perhaps, the more accurate, the observations having been made with the aid of the wire. To determine the total lift of the pump, the elevation of the water on each side of the wheel was carefully noted and found to have been 3.049 ft. The temperature of the water was uniformly 39°, and the weight at that temperature was assumed to be 62.424 lbs. per cubic foot. During the trial the total number of revolutions were 74 658, or an average of 51.8458 per minute, and the total amount of coal used was 14 750 lbs., hence the duty developed was 75 944 037 foot-pounds per 100 lbs. of coal consumed without deductions of any kind, and the volume displaced during the 24 hours equal to 58 854 395 cu. ft., or 440 220 867 U. S. galls., which is about the average daily work this engine has been performing during its regular run for nearly nine months in the year. At a speed of 59 revolutions per minute, this pump displaces 500 966 605 U. S. galls. per 24 hours, which is believed to be the largest quantity of water handled by any single machine in the world.

The above duty has since been exceeded, for, at the time the above test run was made, the engine and boilers had not been entirely enclosed by a permanent building. The average duty developed during last year's run was 74 654 440 foot-pounds, without any deductions for steam used for heating or for operating a 25-light electric dynamo. This also is believed to be the highest duty developed by any style of wheel pumping engine yet made.

Interesting, in connection with the data collected during and after the test run, is the fact that the value of the coefficient in the formula $v = c\sqrt{ri}$ for tunnel or conduits of 12 ft. diameter for velocities from 5 to 7 ft. per second is found to be from 122.7 to 128.3, with an average of 124.9 for these velocities.

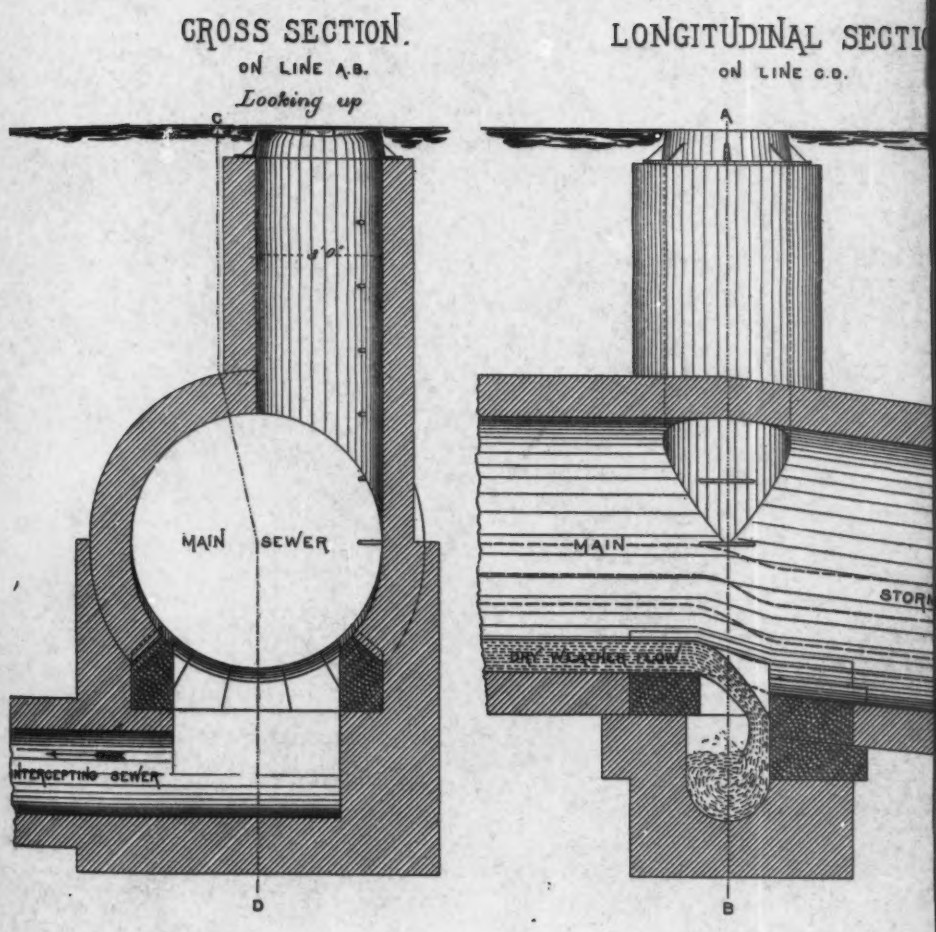
DATA OF OFFICIAL TRIAL OF DECEMBER 1ST-2D, 1888.

Duration of trial	24 hours.
Average steam pressure by gauge	102 lbs.
Average vacuum pressure by gauge	26 ins.
Total revolutions of engine	74 658
Average revolutions of engine per minute	51.8458
Piston speed, per minute	414.76 ft.
Average indicated H. P	325.47
Total coal (anthracite) fired to furnace	14 750 lbs.
Total ash and clinker	1 810 "
Square feet of grate area in use	56.25
Square feet of heating surface in use	2 025
Total water fed to boilers	109 890 lbs.
Temperature of feed water	120.62°
Temperature of water pumped	39°
Weight per cubic foot of water pumped	62.424 lbs.
Total lift of water pumped	3.049 ft.
Cubic feet of water pumped per revolution	788.32
Cubic feet of water pumped per minute	40 871.1
Cubic feet of water pumped during trial	58 854 395.
Duty developed, per 100 lbs. of coal actually fired	75 944 037.

DATA OF CAPACITY TESTS AND OBSERVATIONS.

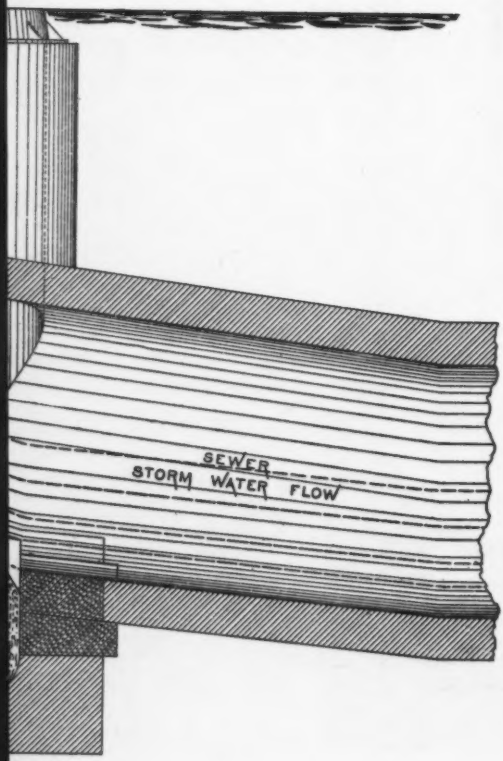
Length of tunnel between points of observation	2 534 ft.
Length of tunnel between center of shafts	2 504 "
Sectional area of tunnel per foot	113.09 cu. ft.
Total capacity of tunnel between above points	286 570 "

Date of tests.	No. of tests.	Average number of revolutions per minute.	Observed time of flow through tunnel.	Total number of revolutions.	Actual velocity in feet per second.	Cubic feet water displaced per revolution.
1888.						
November 14.....	1	42.44	8′ 28″	359.32	4.988	797.53
"	2	42.60	8′ 12″	349.32	5.150	820 36
"	3	47.29	7′ 29″	353.89	5.640	809.77
"	4	47.29	7′ 31″	355.46	5.618	806.19
"	5	50.71	6′ 56″	351.59	6.091	815.07
"	6	50.33	7′ 02″	353.99	6.005	809.54
"	7	55.00	6′ 25″	352.92	6.582	812.00
"	8	54.60	6′ 29″	353.99	6.514	809.54
"	9	58.20	6′ 14″	362.78	6.775	789.93
"	10	58.60	6′ 8″	359.41	6.886	797.33
November 18.....	1	25 00	14′ 55″	372.92	2.831	768.45
"	2	25.61	14′ 34″	373.05	2.899	768.19
"	3	41.78	8′ 34″	357.92	4.930	800.65
"	4	42.44	8′ 27″	358.62	4.998	799.09
"	5	60.33	5′ 54″	355.95	7.158	805.09
"	6	60.16	5′ 53″	353.96	7.178	809.61
November 23.....	1	50.57	7′ 11″	363.26	5.879	788.88
"	2	51.17	7′ 5″	362.45	5.962	790.64
"	3	51.29	7′ 7″	365.01	5.934	785.10
"	4	lost.				
"	5	51.85	6′ 56″	359.49	6.091	797.16
"	6	52.00	7′ 3″	366.60	5.990	781.70
"	7	lost.				
"	8	51.62	7′ 2″	363.06	6.005	789.31
December 1.....	1	53.11	6′ 53″	365.57	6.136	783.90
"	2	52.00	6′ 58″	362.27	6.062	791.04
"	3	51.71	7′ 5½″	366.49	5.959	781.93
"	4	52.67	6′ 55½″	364.52	6.102	786.16
"	5	52.57	6′ 48½″	356.38	6.229	804.11
"	6	52.80	6′ 55½″	365.86	6.095	783.28
December 2.....	1	52.16	6′ 48½″	354.90	6.207	807.46
"	2	52.57	6′ 49″	358.35	6.195	799.70
"	3	52.14	6′ 51¾″	357.81	6.154	800.90
"	4	58.67	6′ 11¼″	363.26	6.821	788.88
"	5	58.83	6′ 4″	356.92	6.961	802.90
"	6	59.17	6′ 8¾″	363.63	6.872	788.08
"	7	59.23	6′ 8″	363.27	6.886	788.86
"	8	43.41	8′ 22½″	363.56	5.043	788.23
"	9	43.30	8′ 18½″	359.75	5.083	796.58
"	10	33.73	10′ 52″	366.53	3.886	781.84
"	11	33.90	10′ 39″	361.03	3.965	793.75
"	12	25.38	14′ 5¾″	357.75	2.996	801.00
"	13	25.70	13′ 59″	359.37	3.020	797.42


CROSS SECTION.
ON LINE A.B.
Looking up
C
3'0"
MAIN SEWER
INTERCEPTING SEWER
D
LONGITUDINAL SECTI
ON LINE C.D.
A
MAIN
STORM
DRY WEATHER FLOW
B

DINAL SECTION.

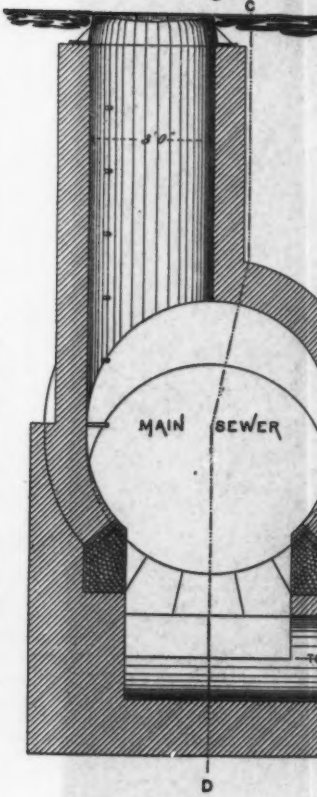
LINE C.D.



CROSS SECTION

ON LINE A.B.

Looking down



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B.

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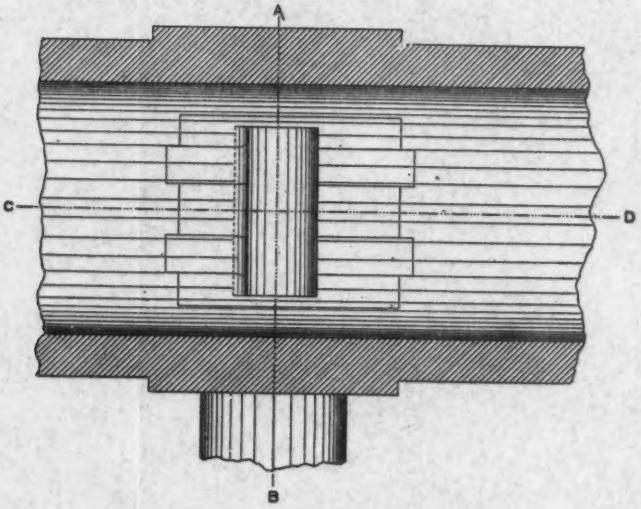
R

TO INTERCEPTING SEWER.

HORIZONTAL SECTION
ON CENTER LINE.



INTERCEPTING ARRANGEMENT
of the
Fourth Ave. Main Sewer
AT
PARK ST.

SCALE.

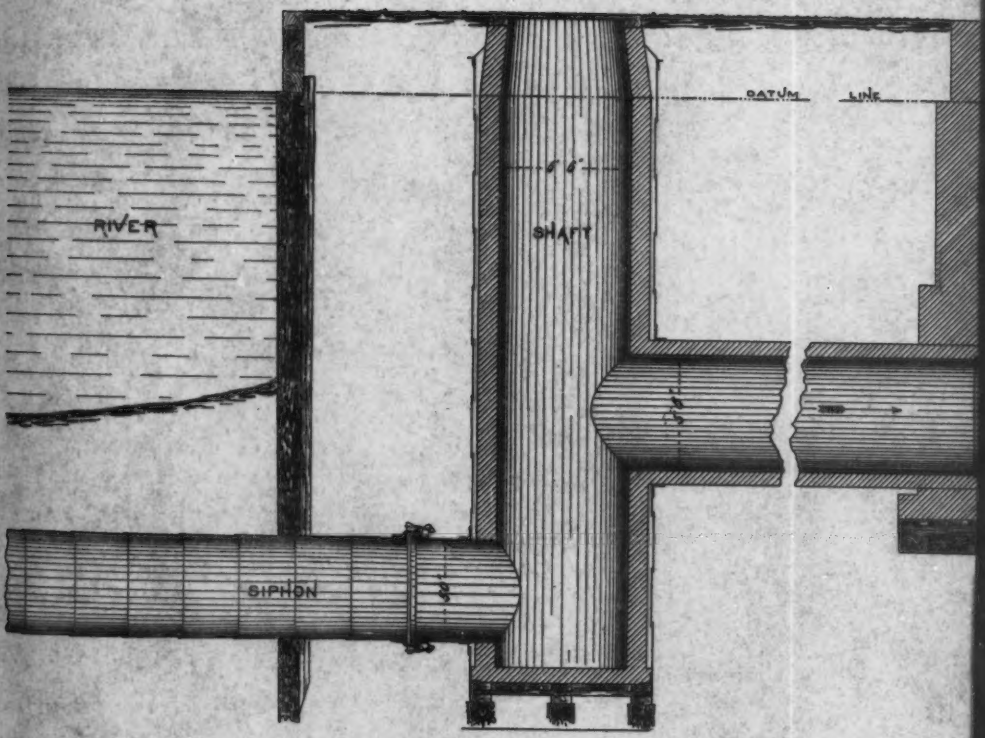
0 1 2 3 4 5 6

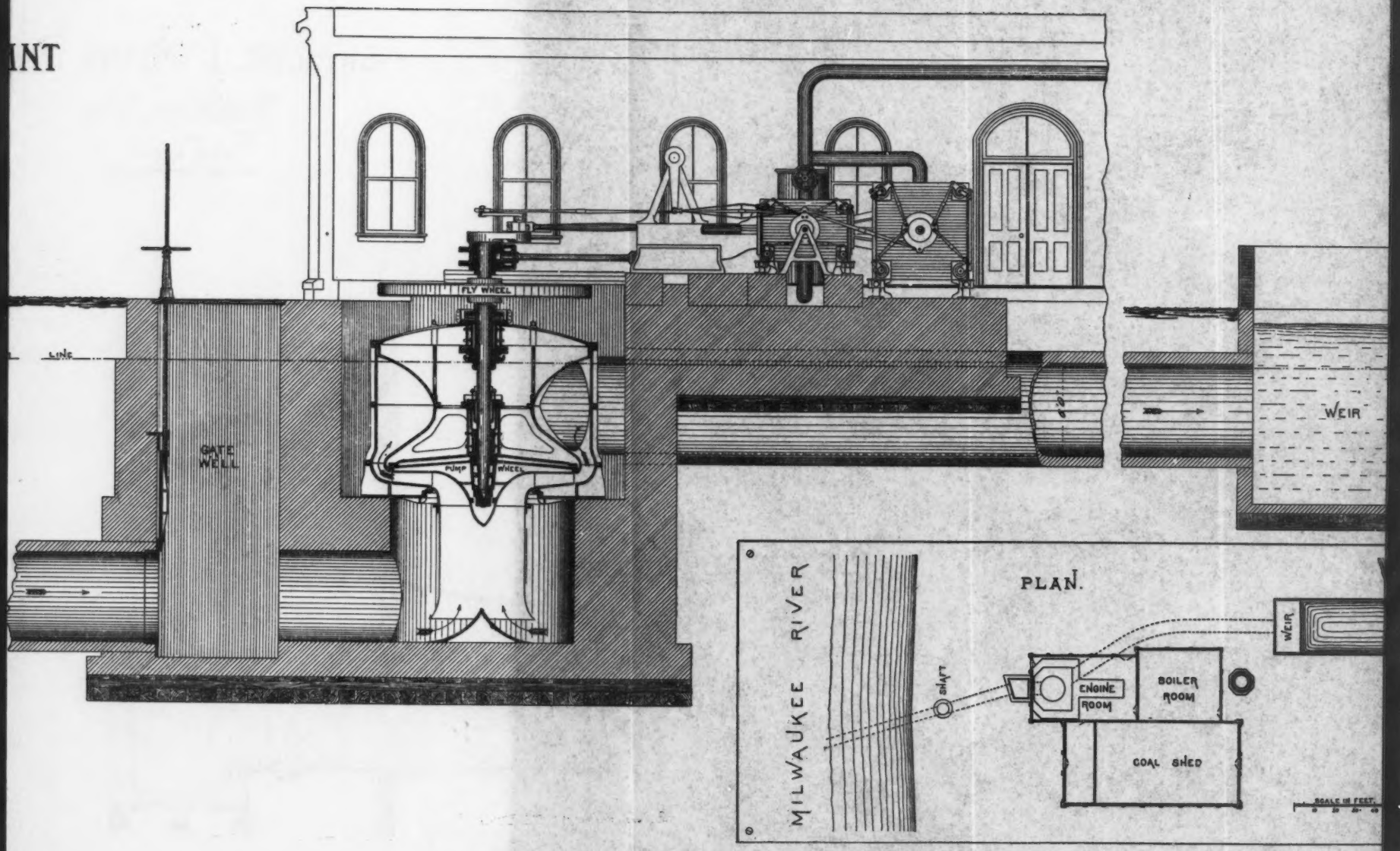
SEWERAGE PUMPING PLANT

Milwaukee, Wis.

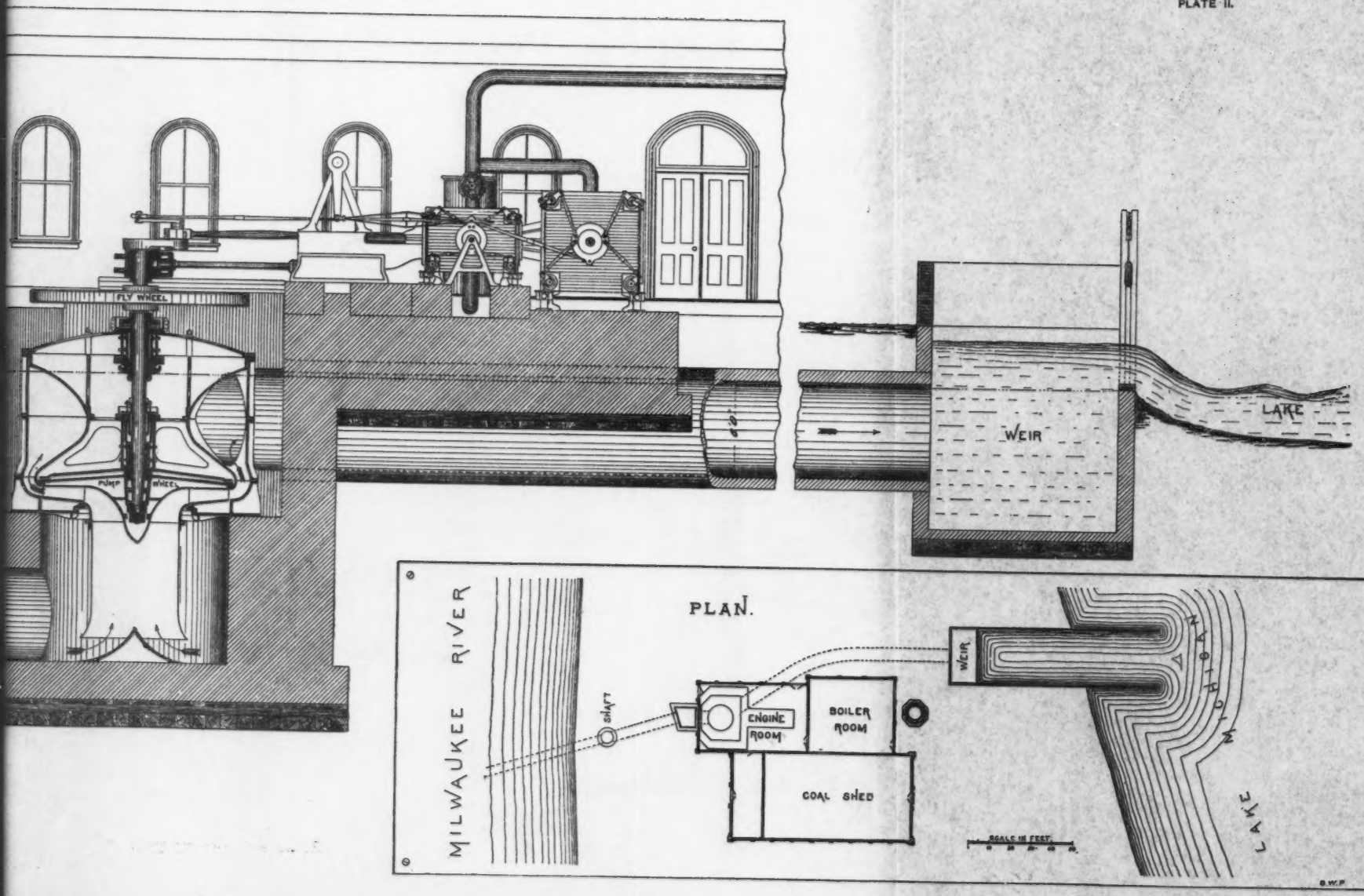
Scale in feet.

0 1 2 3 4 5 6 7 8 9 10




FLY WHEEL
GATE WELL
PUMP WHEEL
WEIR
PLAN.
MILWAUKEE RIVER
SHAFT
ENGINE ROOM
BOILER ROOM
COAL SHED
WEIR
SCALE IN FEET.

VOL. XXX, No. 651.
TRANS. AM. SOC. CIV. ENGRS.
BENZENBERG ON SEWERAGE SYSTEM OF MILWAUKEE.
PLATE II.



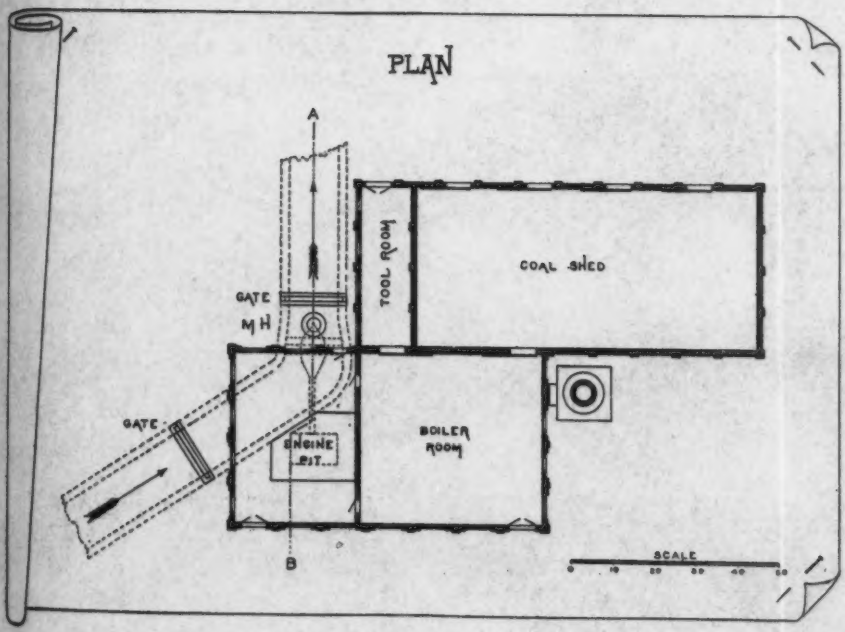
Milwaukee River Flushing Works.

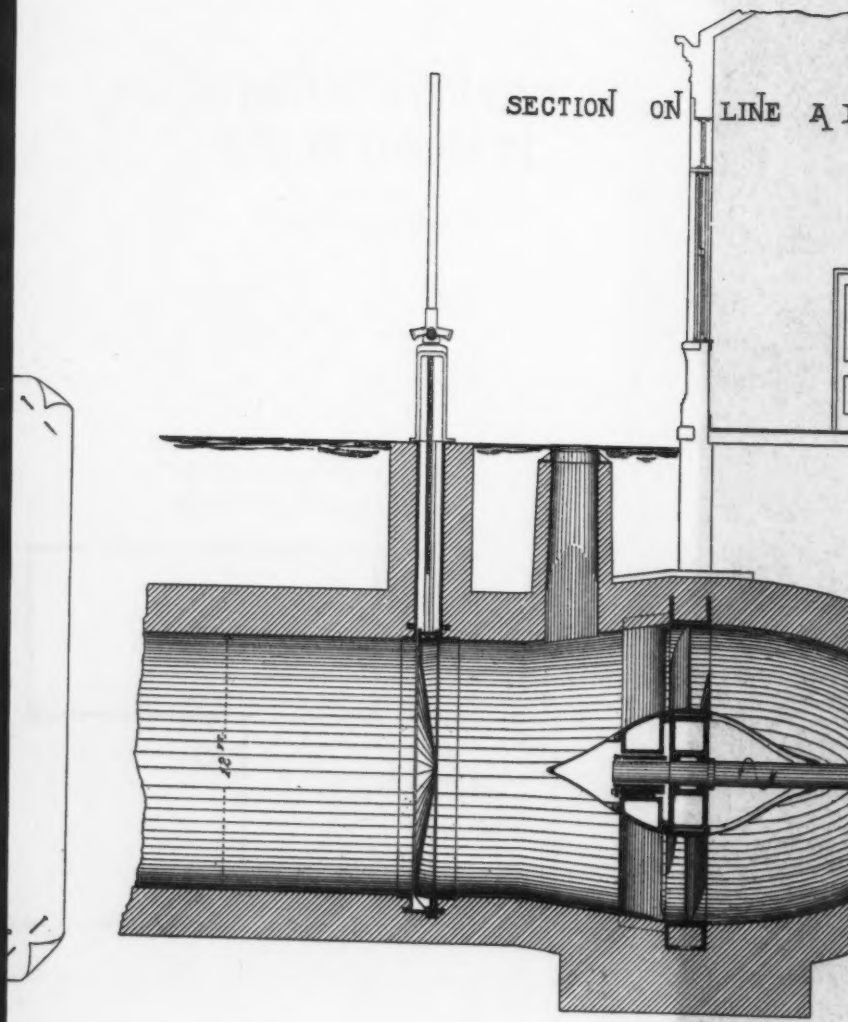
PUMPING PLANT

SCALE.

0 1 2 3 4 5 6 7 8 9 10

FEET.




SECTION ON LINE A

VOL. XXX, No. 651.
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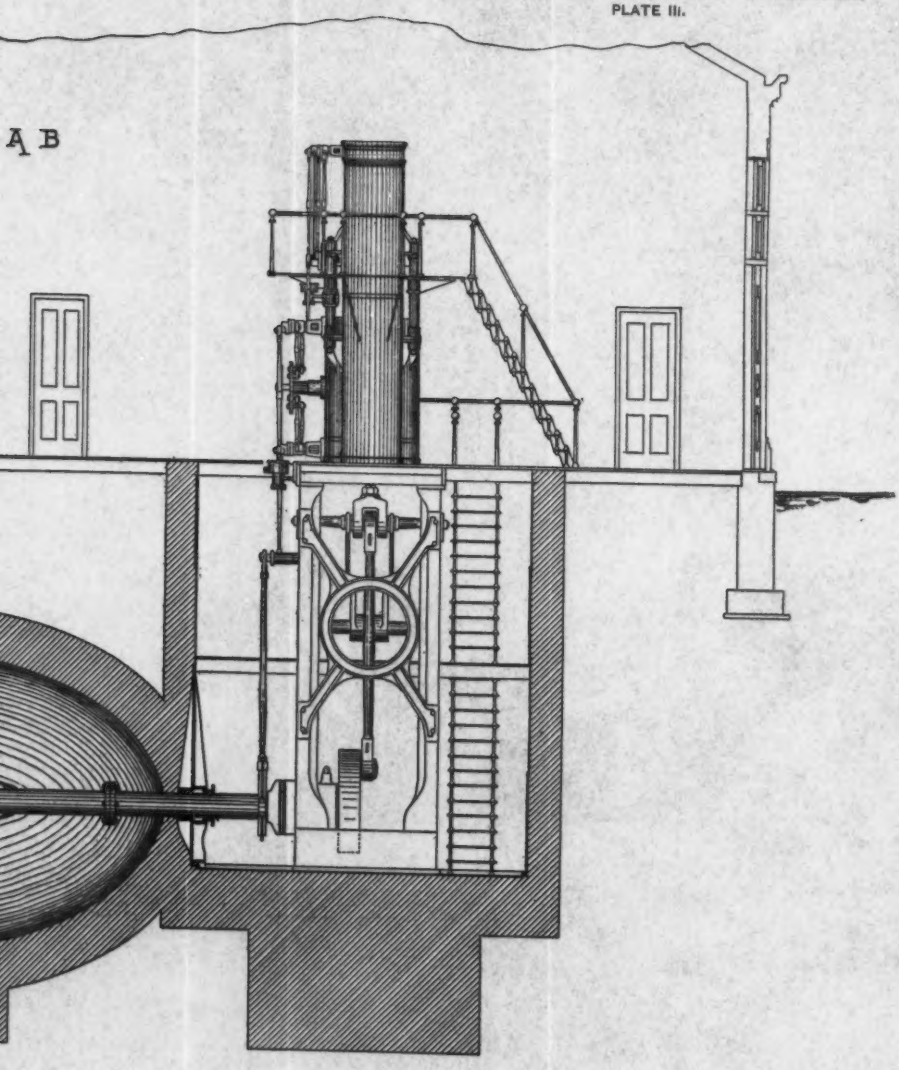
BENZENBERG ON SEWERAGE SYSTEM OF MILWAUKEE.
PLATE III.



No. of test.	Observed time of flow through tunnel.	Actual velocity in feet per second.	Observed difference in water level in shafts 2 504 ft. apart.	Average observed head per 1 000 ft.	Coefficient (C) of formula $v = (c)\sqrt{ri}$
			Feet.		
4.....	6′ 11½″	6.821	{2.48} {2.58}	1.010	124.02
5.....	6′ 4″	6.961	{2.63} {2.58}	1.040	124.30
6.....	6′ 8½″	6.872	{2.62} {2.62}	1.046	122.71
7.....	6′ 8″	6.886	2.62	1.046	122.96
1.....	6′ 48½″	6.207	{2.09} {1.88}	0.793	127.19
2.....	6′ 49″	6.195	{2.04} {2.07}	0.821	124.90
3.....	6′ 51½″	6.154	{2.11} {1.97}	0.814	124.57
8.....	8′ 22½″	5.043	{1.31} {1.40}	0.541	125.13
9.....	8′ 18½″	5.083	{1.35} {1.27}	0.523	128.35
10.....	10′ 52″	3.886	0.67	0.268	137.31

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652.

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THE ENLARGEMENT AND IMPROVEMENT OF THE NORTH SEA CANAL OF HOLLAND (AMSTERDAM SHIP CANAL).

By A. E. KEMPEES, C. E., Royal Engineer in Holland.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

The North Sea Canal of Holland.—The North Sea Canal (also known by the name of "Canal through the narrowest part of Holland") is the high road of commerce from the North Sea to Amsterdam, and is continued further eastward as far as the Zuyder Zee.

A description of the important works, which about twenty years ago were in course of construction in connection with the digging of this canal, has been given by Brevet Major-General J. G. Barnard, in the "Professional Papers of the Corps of Engineers of the United States

NOTE.—Discussions on all papers presented to the International Engineering Congress will be published simultaneously in the number for December, 1893.

Army." Another account of the works executed before 1874 may be found in the well-known paper of M. Ph. Croisette Desnoyers, Ingénieur en Chef des Ponts et Chaussées, under the title, "Notice sur les Travaux Publics en Hollande."

The above-mentioned papers being known to the whole professional world, it may be judged superfluous to repeat what has been so correctly stated in them.

This paper is a sequel to those writings, and will endeavor to sketch in strict outlines what has been done since 1872 for the completion, maintenance and improvement of the North Sea Canal.

It is a well-known fact that the execution of the plan was undertaken by the Amsterdam Canal Company. This company found numerous technical as well as financial difficulties in its way. It is not to be denied, indeed, that on several occasions it met with the powerful support of the Government, but in the long run the means of carrying out the task failed, and on the 31st of October, 1881, an agreement was signed by which the company handed over all its possessions and rights, as well as its liabilities and obligations, to the State of the Netherlands. The Act of December 19th, 1882 (*Official Gazette*, No. 231) ratified this agreement.

Before this change in the direction of the works had taken place, they had been executed to such an extent as to have definitely established the new route of communication with the North Sea, to have completed the enclosure in the direction of the Zuyder Zee, and to have reclaimed and sold the several polders in the enclosed part of the Y.

In 1872, on the 10th of March, the locks on the Zuyder Zee side, near Schellingwoude, were opened for public service. They had previously, on the occasion of the laying of the memorial stone (April 29th, 1870) by His Majesty King William III, received the name of "Orange Locks."

In 1874 the sale of the first polder could be made; in 1882 all polders had passed into private hands, with the exception of a small strip of land (polder vii) close to the entrance of a side canal to Zaandam, which is, though surrounded by embankments, not drained. This enclosure is still being used as a deposit for material dredged from the canal.

The harbor on the North Sea having got a navigable channel 5.5

m. deep below Amsterdam water-mark (Amsterdam level, A. P.*) and the canal itself a depth of 6.5 m. below A. P., the route was opened. A few days before the opening ceremony the necessary regulations had been established concerning the tariff of harbor and canal dues and the police regulations to be observed in passing the canal and the works belonging to it.†

A short time after the works had passed into the hands of the Government there was a general call for improvements of the various parts and for the extension and enlargement of the canal and its works. Considerable sums have already been spent for this purpose, extensive works are still being executed, but in order to make Amsterdam accessible to the largest sized vessels many more improvements will have to be carried out.

The present condition of the canal has been indicated in its chief outlines on Plate I. The most important of the new works in course of construction have likewise been represented upon it.

North Sea Harbor.—The outer harbor is bounded by two piers made of concrete, each 1 528 m. long, while the bases of these piers are 1 200 m. apart; their converging direction gradually diminishes this distance to 660 m. at 1 200 m. from the coast line. Then the piers curve inward so as to leave at a distance of about 1 400 m. from the coast line a harbor entrance 260 m. wide. Owing to the deposit of enormous loose blocks of concrete at the heads of the piers, a width of 200 m. remains for navigation.

The area enclosed by the piers (the outer harbor) comprises to the lowest line 92 hectares; to the high water-line, 102 hectares.

At one time an attempt was made to dredge in the outer harbor an elliptic basin having a width of 650 m. and a depth of 8½ m. below A. P. at the entrance, and of 7½ m. below A. P. on the shore side, but the work was stopped. From October, 1878, to November, 1879, 765 000 cu. m. of material, measured in the barges, were raised by dredging; but, notwithstanding this fact, the profile indicated that the material of the harbor had been diminished by but 4 000 cu. m.

At the present time by the aid of powerful dredges a channel of 250 m. width, 8.5 m. deep below A. P., is maintained; while, accord-

*A. P. means Amsterdamsch Peil, the average level adopted as a standard throughout the Netherlands by the King on the first of November, 1876, at which time the new harbor received the name of Ymuiden (mouth of the Y).

† Royal decrees of October 20th, 1876, *Official Gazette*, No. 27, and October 26th, 1876, *Official Gazette*, No. 189.

ing to the conditions of the present dredging contract, that channel will have to be deepened in 1894 to 9.50 m. below A. P. for a width of 250 m.

In order to perform this dredging, carried on also beyond the harbor mouth, and to which must be added the keeping at the requisite depth of the inner canal leading up to the North Sea locks, the following dredging plant must constantly be in good working condition at Ymuiden:

(*a*) Two hopper pump dredges of sufficient capacity to raise 455 and 610 cu. m. per hour of the matter found in and near the harbor mouth from a depth of 12 m. below the sea level.

The pump dredge, whose capacity is 610 cu. m. per hour, shall at the same time be fitted with ladder and buckets, to dredge in a draught of water of 11 m.

(*b*) Two stationary bucket ladder dredges of sufficient capacity each to raise and discharge into scows 270 cu. m. an hour of the material found in the harbor and in the outer canal.

One of these dredges must be able to do this work in a draught of 11 m., the other in a draught of 10 m.

(*c*) Five steam hopper barges, so-called "*ouderlossers*" (discharging dredgings through traps or valves in the bottom) with a capacity each of at least 150 cu. m.

Three of these steam hopper barges must be fitted with pump dredging machinery, two of sufficient capacity to raise at least 150 cu. m. of dredging matter per hour in a draught of water of 11 m. in and near the harbor mouth, the third to raise at least 285 cu. m. in that time.

(*d*) A large steam-tug of about 150 I. H. P., built and fitted up to serve as a direction steamer to the surveying staff.

(*e*) A sufficient number of reserve engine-parts, of which a full supply is constantly to be kept in readiness for immediate service in case of repairs being necessary.

The dredgings are discharged into the open sea at distances of at least 5 000 m. from the coast line wherever at a sea level corresponding to A. P. a draught of water of at least 13 m. is found. The quantity of material that has yearly to be removed in order to maintain the requisite depth, and in order to obtain the greater depth now desired, is enormous.

The following tables give an idea of the quantities raised since 1876. These quantities were not measured in place, but in the vessels used for transportation.

Year.	Outside the harbor's mouth. Cubic Meter.	In the harbor. Cubic Meter.	In the outer canal. Cubic Meter.
1876	.....	501 956	
1877	.....	936 804	
1878	53 118	1 642 098	19 009
1879	83 752	438 764	43 050
1880	47 424	264 085	27 920
1881	63 381	394 359	60 875
1882	86 413	390 124	37 710
1883	50 538	387 485	62 894
1884	69 775	504 122	84 875
1885	45 819	375 902	52 263
1886	83 257	550 829	36 035
1887	75 155	401 391	22 120
1888	56 370	376 055	30 900
1889	59 605	364 200	14 485
1890	82 848	368 917	18 710
1891	61 325	402 575	20 300
1892	87 905	751 455	39 120

During a considerable part of the year, the surf and swell made dredging impossible. The number of days when dredging could not be done amounted to—

Year.	Outside the harbor mouth.	In the harbor.	Year.	Outside the harbor mouth.	In the harbor.
1883	240	156	1888	270	136
1884	263	193	1889	227	103
1885	298	204	1890	207	119
1886	241	165	1891	255	126
1887	265	130			

The piers protecting the harbor against the North Sea were finished for their entire length in 1877.

During the construction of these works on a sandy beach exposed to the violent attacks of the North Sea, many difficulties and disappointments had to be faced.

From the outset it had been the intention to construct these piers of heavy concrete blocks. The dimensions, as well as the formation of these blocks, have often during the progress of the work been altered, while the cross-section of the piers appeared to be in urgent need of enlargement.

On Plate II the different modes of construction have been given in detail.

The original plan of the piers was based upon the system adopted at many English ports, where on a rocky foundation soil, from which the upper layer of clay or sand has been removed, a massive wall with almost perpendicular sides is erected without any protection of the foot against abrasion being necessary.

The inefficiency of similar constructions on the Dutch coast soon manifested itself in an unmistakable manner. Figs. 1 and 5 of Plate II, showing cross-sections of the North Pier as it was first made, remove all doubt on this subject.

At that period only the side fronts of the pier were constructed of concrete blocks prepared in advance; between those walls a nucleus of sand originally, of concrete afterwards, was inserted.

After the winter of 1867, when some experience had already been gained, the pier was constructed entirely of blocks of concrete prepared in advance, the bottom layer of which had imbedded itself into the sand and had afterwards been trimmed to a horizontal plane by the divers (Fig. 2).

This way of proceeding was relinquished for the one sketched in Figs. 3 and 4, which gave a solid basis to the work by the application of a rubble of basaltic blocks forming a stratum 1 m. high between lines of concrete blocks (Fig. 3), and protruding as far as 10 m. beyond the foot of the piers.

Notwithstanding these alterations, the end had by no means been gained. Figs. 8 and 9 certainly do not, in giving a faithful representation of the condition of the north pier at 700 m. from the coast line, convey any notion of a work in every respect a match for a sea that can so mercilessly lash the Dutch coast.

In 1873 a commission of experts was appointed by Royal decree for the purpose of investigating some questions relating to the North Sea Canal.

One of these questions was: "Are the North Sea piers to be judged of sufficient capacity, both as regards construction and strength of materials, and, if not, what are the improvements required?"

Up to that time the concrete blocks for the side facings of the piers had been composed of 1 part of Portland cement to 4 parts of sand (from the sand hills) and 5 parts of gravel.

The blocks were 1.067 m. (3 ft. 6 ins.) high, 1.219 m. (4 ft.) broad, and 1.524 m. (5 ft.), 2.134 m. (7 ft.) and 2.743 m. (9 ft.) long.

The Commission arrived at the following conclusions:

The nethermost blocks do not form a fixed basis, and the upper blocks are stated to shift places to a considerable degree.

The basis has not, at least from the sea side, been sufficiently secured against abrasion.

The Commission was further of opinion that the formation of the mortar used for the blocks, and also the dimensions of the same, were insufficient.

Accordingly it proposed:

First.—To start from the principle, in securing the basis, of the protection having to be carried on to the greatest depth found alongside the work.

And, although it cannot *a priori* be made out what breadth will be sufficient, the Commission feels justified in assuming that the basis to be constructed on the bottom of the sea should protrude at least 10 m. on that side of the piers facing the sea beyond the foot of the rubble to be mentioned below, as the breakwater will be deposited on that basis.

The bottom layer is to be carried on round about the heads of the piers for the same breadth and to be continued as far as will appear necessary along that side of the piers facing the harbor.

As to the remaining part of the harbor front, wherever, during the progress of the work, abrasion takes place, the basis to be deposited is also to extend to at least 10 m. beyond the foot of the pier. The height of the bottom layer may be fixed at 1 m.

Second.—To adhere, in protecting the pier from the impetus of the waves, to the principle of depositing at the seaside rubble reaching from the basis to the top of the pier, and thus forming a breakwater in front of it.

The core of this protection may be composed of stone or small concrete blocks; the outer facings of the breakwater should be made of heavy blocks of concrete.

Inasmuch as, in the absence of examples of similar works on the Dutch coast, the Commission dare lay down an opinion, it ventures to propose the following dimensions to be given to the breakwater:

The nucleus of stone or smaller blocks of concrete may reach to 1.5 m. below the low water-line, with a top breadth at that level of no more than 3 m., and an outward slope 1.5 to 1. The facing

of heavy blocks covering the nucleus is to reach to the top of the piers, *i.e.*, to 4.10 m. above A. P., and to have a top breadth of at least 3 m. by an outward slope no steeper that 1 to 1.

The minimum weight of the blocks to be used for that purpose is to be fixed at 20 tons.

The rubble (breakwater) is to commence, for the north pier at 650 m., for the south pier at 750 m., from the coast line, go round the heads of the piers, and to be continued inward as far as will prove necessary.

The Commission does not judge it proper to give definite specifications for the formation of the concrete, but wishes merely to observe that the mixture hitherto used is of too weak a nature; the proportion of Portland cement ought to be increased, and sharp sand should be used instead of sand from the beach.

As for the piers themselves, it is observed that the parapet should be done away with on the north pier from 650 m. and on the south pier from 750 m. from the coast line, and that the piers should be fully raised to the level to which the top of the parapet now reaches. The top part, to be raised to the level of the actual parapet, should be one homogeneous mass across the whole section. A weight of 10 tons per block is judged necessary for the piers above low water.

In consequence of these remarks, the piers were given the cross-section traced on Plate II, Fig. 6. The blocks of concrete were composed of 1 part of Portland cement, 3 parts of sharp sand and 5 parts of gravel. Experience has taught that blocks of this formation can stand the attacks of the waves and the weather better than those previously used. The piers, as well as the breakwaters, continually require great sums for repairs.

In 1881, by way of experiment, the crown of the north pier was coated with masonry of hard-burnt bricks in strong mortar of Portland cement. This experiment was a complete success, and at the present moment both piers have this protection along their entire length. Fig. 7, Plate II, may now be considered as the type of cross-section of the piers.

The present formation of the concrete blocks for the breakwaters is 2 measures of Portland cement, 3 measures of sharp sand and 5 measures of clear gravel. The largest blocks are 3 m. long, 1.5 m. broad and 2 m. high. Their weight is about 19 500 kg. (20 tons).

On Plate III the present condition of Ymuiden Harbor has been reproduced.

The direction of the axis of the harbor is indicated by means of two white, fixed, dioptric lights of the first order. The western (or outer) light reaches to 41.6 m. above ordinary high water, and is visible at 18 nautical miles; the inner or eastern one reaches 51.5 m. above high water, and is visible at 19 miles. The lights are 560 m. apart and placed in round iron towers, painted with broad white bands.

On the heads of the piers are fixed lights of the sixth order, reaching to 12.7 m. above high water, and are visible at two miles. The north pier light is red at the seaside and green at the harbor side; the south pier light is green at the seaside and red at the harbor side. The lamps have been constructed so as to keep alight several days and nights running whenever the piers are inaccessible on account of bad weather.

Between the piers the navigable channel is indicated by five black buoys on the north side and five white ones on the south side. During dense fogs a steam siren whistle is worked, placed near the western light tower.

Since the opening of the canal a semaphore or coast signaling station has been erected at Ymuiden in connection with the telegraph service. This semaphore has been placed on the south side, near the outer light tower. In accordance with the "Universal Code of Signals," messages can be sent to and received from ships.

The harbor number of Ymuiden is 3. The average difference between tide and ebb is 1.6 m. at neap tide and 1.8 m. at spring tide. Water signals are hoisted at the yardarm of the semaphore's signaling mast in order to indicate every change in the draught of water. These signals, by night and by day, are given on Plate IV.

A few hundred yards inland, between the sandhills north of the harbor, is a beacon, placed so that the azimuth of the line (compass beacon—light on the head of the south mole) is S. 77° 34′ 24″ W. Two lifeboat stations are in close proximity to the harbor.

Sailors will find exhaustive information on the hydrographic chart of Ymuiden and in the accompanying description, published by order of the Naval Office, and in Halverhout & Zwast's "Guide to the Harbor of Ymuiden and the North Sea Canal."

The harbor between the piers cannot, in stormy weather, be consid-

ered a harbor of refuge, in the proper sense of the word. Experience has taught that, generally speaking, it may be entered by ships without any danger at all. During gales, when the passage through the locks was impossible, necessity has sometimes turned it into a harbor of refuge, not unsuccessfully. As a rule, however, vessels, after entering the harbor, should make for the outer canal with the least possible delay, to pass on to the canal through the North Sea locks.

It is worth mentioning that even in the exceptionally severe winter of 1890 and 1891 the traffic in the harbor of Ymuiden was only suspended for a very few days. The navigation in the North Sea Canal itself was in that winter attended with extraordinary difficulties, and was for a considerable time altogether suspended. Measures are planned to prevent similar suspension of traffic in the future by the aid of powerful ice-breakers.

The outer canal or inner harbor enters into the outer harbor between two stone moles on the heads of which fixed white harbor lights have been placed. These lights reach 5.3 m. above high water, and are visible at two miles. The outer canal is 1 430 m. long; it is kept at a depth of 8.5 m. below A. P. This depth is to be found in a channel gradually narrowing from 109 to 38 m. near the North Sea locks.

In virtue of the conditions of the present maintenance contract, this canal will have to be deepened to 9.5 m. below A. P. on July 1st, 1894. The bottom width will, at that time, be 85 m. at the entrance, and 35 m. near the locks. The banks of the outer canal are protected below A. P. by osier work, and above that level by stone sloping.

An enlargement of the outer canal, at the north side, now serves as a mooring place for numerous fishing craft, for whose convenience five jetties have, moreover, been built at the south side. With a view to the great development of the Ymuiden fish trade an area of 17 hectares has been purchased at the south side of the outer canal where a fisheries harbor will be dug.

The plans for the construction of that harbor are still preparing, but meanwhile large quantities of sand have been removed from the purchased grounds. This sand, as will afterwards be seen, is utilized in constructing a bar in the open Y, near Schellingwoude.

The outer canal, as yet, only leads to the set of locks already described on the twenty-eighth and following pages of the before-mentioned paper by Brevet Major-General Barnard.

The principal dimensions of these locks are:

Great tide lock, containing three pairs of tide gates, and two pairs of ebb gates, width, 18 m.; depth, 7.9 m. below A. P.; length of the combined lock pond, 120 m. The lock chamber is divided into two sections by a pair of tide gates. These sections are 70 and 50 m. long.

Small tide lock containing three pairs of tide gates and two pairs of ebb gates, width, 12 m.; depth below A. P., 5.14 m.; length of the lock pond, 70 m.

Outlet sluice containing two pairs of tide gates and one pair of ebb gates, width, 10 m.; depth below A. P., 5.14 m. The outer tide gates reach to 5 m. above A. P.; the highest storm-tide known at Ymuiden, on December 12th, 1883, ran up to 3.30 m. above A. P., near the locks.

Some years after the opening of the locks to trade, the conviction was arrived at that their dimensions were too small for large-sized craft.

As far as their length was concerned, this difficulty could be evaded either by locking the big vessels between the outermost tide gates and the innermost ebb gates (giving an increase of length of 8 m.), or by allowing them to pass at the moment when the tide, being on a level with the water in the canal, did not require any of the gates to be shut. Both these expedients offer peculiar difficulties and impede the regular course of traffic. But, as far as width and depth were concerned, nothing but the construction of new locks could remove these obstacles.

As early as 1885, a plan was sketched in outline for the building of a second great tide lock. According to this sketch the new lock was to have obtained a width of 25 m. at the level of the canal, and a depth of 8.5 m. below A. P. The length of the lock chamber was to have been 205 m., while a pair of intermediate gates was to divide it into two sections about 75 and 130 m. long. The outer front was to have retreated inland about 400 m. from that of the existing locks, the longitudinal axis to have been fixed about 180 m. north of the axis of the present canal. New branch canals would have had to connect these locks with the inner and outer canals.

On August 28th, 1886, a project for a law was offered to the Second Chamber of the States General authorizing the appropriations necessary for the enlargement of the harbor and locks of Ymuiden.

This project embraced the construction of the aforesaid fisheries harbor, as well as the building of a new lock of the above capacity. The cost of these works were then estimated at 4 246 900 guilders. The bill authorizing the appropriation was passed and published in the *Official Gazette*, No. 98, of May 31st, 1887. Very soon afterwards the elaboration of the plan for the lock was proceeded with. The necessary inquiries into the nature of the grounds, including five borings, were made. These borings showed that the soil was almost exclusively composed of sand or sand mingled with shells. Only here and there at different depths vestiges of clay were met with. At a depth between 17 and 19 m. below A. P., a substratum of solid loam was found supported by very solid and dry peat. This foundation soil might, therefore, be called of excellent stability, and the use of piles, unavoidable in the construction of most important works on the Dutch soil, is here superfluous.

There were fears, however, that the sand reaching down to so enormous a depth would throw almost insurmountable difficulties in the way of the execution of the work. The proximity of the present canal, which would be separated from the excavation by an embankment of only about 60 m., and that the top, justified the fear of a great strain of water from which inroads of sand might be expected. These considerations led to the conclusion that the foundations of the lock walls would have to be made under water by means of compressed air, and the walls and floors would have to be constructed thereon between iron fencings. The nether part of the side walls of the locks would have to be constructed of piled-up blocks of concrete.

During the elaboration of this project of foundations by means of compressed air, the digging and dredging necessary for these foundations were separately contracted for, together with part of the inner junction canal (for 348 500 guilders), and also the construction of 6 030 cu. m. of concrete blocks for the side walls (for 96 900 guilders). Permission was moreover granted to several private people to carry off sand from the grounds, while another portion was turned to account in constructing military works on the Amsterdam line of defense.

On October 30th, 1888, the interior digging for the locks commenced; for the most part excavators were used, the material being transported by rail to the beach north of Ymuiden. Although it had been taken for granted that in making the excavation a great

quantity of the matter would have had to be raised by dredging, it appeared during the progress of the work that even at a depth of 11 m. no leak was to be discovered. The water filtering through the adjacent downs, and through the embankment between the excavation and the North Sea Canal, could easily be pumped out by a few centrifugal pumps. In the days of the greatest influx of water the quantity thus removed never amounted to more than 8 000 cu. m. per 24 hours.

Towards the close of the year 1889, the plan of the lock built on foundations by means of compressed air was finished, and on the 27th of December it was to have been contracted for. In elaborating the plan some principal dimensions had been a little increased. The outermost mitre-sill was to have reached to 9 m. below A. P. The intermediate and innermost sills to 9.30 m. below A. P. The total length of lockage had been increased to 225 m., while the width had been kept at 25 m.

In the period intervening between the passing of the appropriation bill and the completion of the plans, the principal dimensions to be given to the locks had formed a subject of controversy in the daily papers and in various technical periodicals. Many professional men backed the opinion that, for the depth, the figure adopted by the Government ought to be increased. The subject was also discussed in the Second Chamber of the States General, and on December 20th, 1889, a considerable majority voted for the mitre-sills being lowered to at least 10 m. below A. P. Accordingly no contract could be made for the construction of the lock and the plan had to be recast.

As a result of the experience gained meanwhile with respect to any danger of inundation threatening the excavation, it was resolved not to put in foundations by means of compressed air and to build the locks on a basis of concrete.

The contractors of the interior diggings agreed to make the concrete foundations of the lock walls for 536 750 guilders. According to the conditions of the agreements drawn up for this purpose, grooved sheet piling has been applied around the four sides of each front lock wall and in front and at the back of each side wall. The sheet piles are 0.15 to 0.20 m. broad, 8 m. long, and their points reach to 16 m. below A. P. The bottom of the excavation had previously been deepened to 8.50 m. below A. P. wherever this piling had to be driven in, this driving having been further facilitated by squirting

in water from two sides. More than 2 000 cu. m. of fir wood were used for the formation of these sheets.

Each front wall and each side wall having thus been confined to a separate section, these sections were deepened to 13.70 m. below A. P. by means of a bucket-ladder dredge and a suction pipe, the level of the water during this work being kept at 9 m. below A. P. As soon as a section had reached the required depth, the filling up with concrete was proceeded with.

The concrete was deposited under water through wooden tunnels and in two strata of a thickness of 1.25 m. each. In the front walls these tunnels were moved across a floating scaffolding; for the side walls across braced beams, the tunnels corresponding to the two layers succeeding each other as closely as possible.

In four months, by dint of working night and day, the total bulk of 25 000 cu. m. of concrete had been cast in, the greatest quantity disposed of in 24 hours being 400 and odd cubic meters.

The silt proceeding from the concrete had been removed as much as possible during the execution. On the layer of concrete a layer of sand 2 m. thick was spread, beneath which the whole mass could harden undisturbed during the winter of 1891 and 1892. The concrete was composed of 6 parts of hydraulic lime (Tournay stone lime) measured after the slacking; 5 parts of sharp sand, 7 parts of trass and 17 parts of broken bricks.

These broken bricks had to be for at least two-thirds hard-burned clay, the other third part might be one degree less hard; they might not be larger than 75 nor smaller than 5 cu. cm. The contractors were at liberty to use, instead of hard-burned clay rubbish of Liege limestone, granite or any other hard and granulous stone.

In March, 1892, the removal of the water and the sand overlying the concrete in the different sections was commenced, and it appeared that, with the exception of three places, where springs had creviced the concrete, the foundations were a great success. The upper stratum of the concrete consisted, to a depth of 10 or 20 cm., of loose bricks and sharp sand of some coherency; the underlying concrete had become perfectly hard. The layer of inferior quality was removed with the pickaxe, and in its stead a thin layer of concrete of Portland cement was deposited, on which the masonry of the walls has been erected.

The sheet piling proved to be very tightly closed, in many places thin jets of water indeed squirted through the seams, but it was a very easy matter to remove this water together with that proceeding from the three springs by the help of two centrifugal pumps of a suction-pipe of 20 cm. diameter, so that the surface of the concrete at a level of 11.20 m. below A. P. was laid, comparatively speaking, dry. The site of the springs corresponds pretty closely to the spots where the borings were performed. Their water is fresh and impregnated with few gases, so that it evidently proceeds from underneath the stratum of peat at a depth of 19 m. below A. P.

The general system originally adopted for the repression of these springs was the removal of the bad concrete and the filling up of the hole with strong concrete of Portland cement, an iron tube fitted with a very large circular flange at the bottom having first been stuck in. Through this tube the spring could discharge itself without causing any inconvenience. These tubes might be filled up when the lock was getting finished.

The spring in the foundations of the outermost front wall has been very successfully treated in this way. The tube over this spring discharges 270 cubic dcm. of water per minute. Before the above-mentioned measures were taken, part of the water from the springs found its way alongside the western sheet-piling, but this leak has stopped of its own accord. Fortunately, these bad spots do not at all interfere with any part of the lock which has to resist the pressure of the water.

As a temporary measure, intending to counterbalance the upward pressure by placing a column of water over the damaged parts of the concrete, the spring in the foundations of the outermost front wall has been surrounded by a circular wall, which might now be broken down and thrown in the intermediate foundation by a wooden coffer.

This spring in the foundation of the intermediate lock piers pours forth about 1.2 cu. m. of water per minute. It has been decided to repress these springs by means of compressed air. This process will lay dry the damaged concrete, which will be removed and supplanted by more reliable matter, while the spring itself will again be led off through a tube until the completion of the work. Then the opening may be filled with Portland cement mortar or closed by any other device.

In the beginning of 1891 the plan of the superstructure of the locks had already so far been completed as to allow a contract to be made. This work comprises the building of the three sets of lock piers or front walls, of wings to the outer and inner front walls, and of the side lock walls ; the construction of fascine works outside the locks in front of the gates, and of the paving of the bottom of the lock chamber, besides the digging of branch canals on either extremity of the locks, inclusive of osier work, stone slopings and some works of minor importance.

The cost of the work under this contract amounts to 1 634 964 guilders. It is now under construction.

Plate V gives an idea of this colossal enterprise.

The principal dimensions are now :

Length of the entire lock, 282.16 m. ; length of the lock pond between the outer point of the outermost mitre-sill and the abutment of the outer gate recesses of the intermediate lock piers, 70.445 m. ; length of the lock pond between the point of the outer mitre-sill of the intermediate lock piers and the abutment of the outer gate recesses of the innermost lock piers, 144.445 m. ; length of the lock chamber between the point of the outer mitre-sill of the outermost lock piers and the abutment of the outer gate recess of the innermost lock piers, 225.775 m. ; width at a level of 3 m. below A. P. and lower down, 25 m. ; top of the mitre-sills, 10 m. below A. P. ; top of the copings of the front of the outermost lock piers, 5 m. above A. P. ; top of the copings of the rest, 3.60 m. above A. P.

A number of other dimensions have been indicated on the plate.

The whole building is constructed of brickwork, with limestone facings and granite copings wherever necessary. The lock walls get a front facing of rough basalt down to 3 m. below A. P. The floor of the lock chamber will be paved with blocks of concrete, for which purpose the before-mentioned blocks, originally intended for the construction of the side lock walls under water, will be used. The construction of this lock shows few deviations from the system hitherto followed in the Netherlands. Separate mention should be made of the arrangement to fill and empty the lock, which is as yet only the second of that kind in the Netherlands. On either side, running the whole length of the side walls, have been constructed sluiceways 2 m. wide and 3 m. high, communicating with the lock basin by 11

openings, and closed by double sluice gates or paddles in each of the lock piers. Owing to this arrangement the filling of the lock basin will not, under the most untoward circumstances, take more than 10 minutes, while the inflowing or outflowing currents are distributed so as to cause none but the slightest inconvenience to vessels. Excepting the before-mentioned springs in the concrete foundations, making particular measures peremptory, no accident has delayed the execution of the work up to this date.

The plan of the iron gates is ready, and they, too, will soon be under construction. The way in which the gates and paddles will be worked has not yet been decided upon. The system will be either hydraulic or electric. The whole work will, to all appearances, be completed in 1895.

Starting inland from the North Sea locks, the canal cuts its way through a stretch of sandhills, about 4 700 m. long, to run on through the now drained Wykermeer and through the Y, the waste of waters changed into arable land since the execution of the work.

Due provision has been made for the requirements of the navigation and drainage of the adjacent countries by the construction of some side canals.

These side cuts are the following:

A. To Beverwyk.

B and *C.* To Spaarndam, a place very important, for the drainage of Rhynland (the Rhine polders), where at the same time a set of locks connects the canal with the water-way to Haarlem.

D. Towards Nauerna, where an outlet sluice for the Schermer polder is situated, and at the same time locks give access to that polder.

E. Towards Westzaan, where locks give access to the Westzaan polder.

F. To Halfweg (another important drainage station of the Rhine polders).

G. To Zaandam, a city whose commercial prosperity has greatly increased since the completion of the North Sea Canal. At Zaandam the side canal terminates into three locks partly used for navigation, but at the same time acting as outlet sluices to the Schermer polders.

H. Towards the mill sluice at Barndegat, an outlet for the Oostzaan polder.

I. Towards Oostzaan, where a lock gives access to the polder of that name.

K. Towards Nieuwendam; here a lock gives access to the Waterland polder.

These branch canals may be entered by vessels of the following draught:

For the canals *B, C, D, F*	3.00 m.
" canal *K*	2.80 "
" " *E*	2.20 "
" " *I*	1.80 "
" " *A*	1.50 "
" " *H*	1.30 "
" " *G*	7.10 to 7.30 "

The following table gives some details about the polders reclaimed during the construction of the canal:

Name of Polder.	Area. (Hectares.)	Summer level. Meters below A. P.	Drainage Machines. (All worked by steam.)
Noord en Zuid Wykermeer	482	2.40	1 Centrifugal pump, 12 H. P.
" " Spaarndammer polder	520	2.60	1 " " 12 "
Houtrak polder	1 350	3.00	2 pumps, 80 H. P. (together).
Nauernasche, Westzaaner en Zaandammer polder	612	3.40	1 Centrifugal pump, 20 H. P.
Groote Y polder	1 950	3.10	1 " " 64 "
Amsterdammer polder	400	3.40	1 " " 19 "
Noorder polder	465	3.20	1 " " 20 "

The polders are protected by embankments whose crowns are nearly everywhere at a level of 1 m. above A. P. The breadth is, at the rest, 4 or 5 m. as a rule; the slopes on either side have 4 base to 1 rise.

Within the range formerly occupied by the Y, there is another polder called Benks loter Ham, covering 224 hectares, having a summer level of 2.23 m. below A. P. and for drainage purposes a centrifugal pump of 16 H. P. This polder had been reclaimed before the construction of the North Sea Canal, and as at that time the water of the Zuyder Zee had free access to the Y, it had been surrounded by an embankment much higher than those of the polders afterwards reclaimed. The crown of the dike is 3 to 3.50 m. above A. P.

The market value of the Y territories amounted to more than 2 000 guilders per hectare. On the whole these polders have a very fertile soil.

The North Sea Canal runs along these polders in a succession of long straight sections connected by weak curves, and cuts through only one polder (near Bentenhuizen) which existed before the construction of the canal.

The canal is bridged over at three points; near Velsen there is a swingbridge for ordinary traffic and another for railway traffic; and near Zaandam there is a swingbridge for the railroad from Amsterdam to den Velder.

The railway bridge at Velsen offers a passage 19.20 m. wide, the bridge for ordinary traffic one 19.25 m. wide; the railway bridge near Zaandam two, 19.50 and 19.15 m. wide.

The banks of the canal are further connected by two ferries, at Bentenhuizen, by one near Zaandam and by a steam cable ferry at Amsterdam.

On Plate VI has been drawn, in the first place, the cross profile of the canal at the outset. With regard to the depth it should be observed that the drainage interests of the surrounding country made a level of $\frac{1}{2}$ m. below A. P. desirable, a level which every effort is made to maintain as best may. The drainage and outlet arrangements now extant have to this date proved inadequate to perform this task without interruption, and a higher level is accordingly not unfrequent.

The conditions of the concession (charter) granted to the Amsterdam Canal Company stipulated a depth of 7 m. below the canal level and a bottom width of 27 m., the slopes on either side not to be steeper than 2 base to 1 rise. At the opening of the North Sea locks for traffic, neither the main canal nor the side cuts were found to contain the requisite draught of water. Vessels drawing more than 5 m. could, for the time being, not be admitted to the main canal. Gradually this state of things changed for the better, the profile of the canal was not only deepened, but also enlarged at several points. Even before the opening of the canal the City of Amsterdam had entered into an agreement respecting this enlarging of the canal and this increase of depth to 8.2 m. below A. P., or to 7.7 m. draught.

The task was performed between the years 1877 and 1883, while, in addition, a widening of the canal in the cutting through Bentenhuizen was brought about in 1887. In this way the canal obtained the profile represented in Figs. 2, 3 and 4 of Plate VI.

The present Special Regulations of Police for the North Sea Canal

(established by Royal Decree of May 23d, 1892, *Official Gazette*, 113) allows to vessels entering the canal a maximum of draught, wherever measured, of—

7.30 m.	at a level	of	0.30 m.	below	A. P. and higher.
7.20 "	"	"	0.40	"	" "
7.10 "	"	"	0.50	"	" "

With a view to the draught of inward-bound vessels being increased through their passing from sea water into fresh or brackish water, the regulations direct that for the draught such vessels will get in the canal a standard of 0.1 m. shall be added to their draught in the outer harbor or outer canal. The maximum of breadth allowed to vessels is now 17.75 m. for the main canal; the maximum of length, 115 m., for lockage through the North Sea locks, and 90 m. for lockage through the Orange locks at Schellingwoude. The present dimensions of the canal and harbor are by no means calculated to open the way to the docks of Amsterdam to the largest-sized ships, although they could pass the new locks at Ymuiden. The stages for loading and unloading vessels will also require important improvements before they are fit for the giants of modern navigation.

It is intended to carry out the necessary improvements and enlargements by easy stages, while it is in no way considered peremptory for all the works to have received, at the time the new lock will be completed, dimensions corresponding to those of the latter. The excessive depth, width and length of that lock have been thus fixed, not with a view to immediate necessity, but are reserved for the "ship of the future." On a preceding page mention has been made of an increase of depth to be given to the channel of the outer canal in the years to come.

In 1889, indeed, the deepening of the canal to 9 m. below A. P. was commenced. The work is now in full progress, and will be quite finished in 1896. This enlargement of the canal is due to the notion that for the nearest future it will be sufficient to expect vessels of the following dimensions: Length, 173 m.; breadth of beam, 15.5 m.; draught, 8 m.

On Plate VI, Figs. 5 and 6, the dimensions of this new canal profile have been given.

As the "ship of the future" is anticipated, in connection with the dimensions of the new lock at Ymuiden, a vessel 220 m. long, 20 m.

broad and having a draught of 9.3 m. On Plate VI, Fig. 7 represents the midship sections of two such vessels abreast in a cross-section of the canal.

If Amsterdam, after a short lapse of time, through ever-increasing prosperity, require the profile here sketched for its canal, millions, indeed, will be needed to bring about that consummation, but they would certainly be well spent where the interests of one of the vital parts of the country are at stake. It is hardly necessary to observe that the before-mentioned bridges across the canal will also have to be widened in the future or will have to be supplanted by other arrangements.

The docks and quays at Amsterdam, partly dating from olden times, but considerably improved after the construction of the North Sea Canal, are superintended by the municipal authorities and by the railway companies concerned. The trade of Amsterdam is charged with the responsibility of keeping its docks and harbor up to the requirements of the present time.

A Commission appointed by the Board of Trade at Amsterdam published a short time ago an important account, proposing numerous improvements.*

Amsterdam is the trysting place of international and inland navigation; an extensive system of canals and railroads connects the city with all the parts of the country. The North Sea Canal itself extends eastward as far as the Schellingwoude Dam, where ships are admitted to the canal connecting Amsterdam with the River Merwede, and where the Orange locks are, day and night, giving a passage to a countless fleet of fishing and other small craft from the Zuyder Zee to Amsterdam and *vice versa*.

The embankment and also the locks at Schellingwoude have already been described in the paper by J. G. Barnard. No change worth mentioning occurred to these works after the completion of the canal.

The principal dimensions of the locks may be here recapitulated.

Great tide lock, containing three pair of flood gates and two pair of ebb gates, width, 18 m.; depth, 4.5 m. below A. P.; length of the lock pond, 96 m.

Northern small lock, containing three pair of flood gates and two

* Report of the Commission for the Encouragement of Transit Traffic *via* Amsterdam to the Board of Trade and Industry at Amsterdam (Amsterdam Municipal Printing Works, 1891).

pair of ebb gates, width, 14 m.; depth, 4.5 m. below A. P.; length of the lock pond, 72.80 m.

The southern small tide lock is exactly the same as the northern.

Outlet sluice containing two pair of flood gates and one pair of ebb gates, width, 10 m.; depth, 4.50 m. below A. P.

Drainage sluices underneath the drainage machine; three openings containing a pair of ebb gates and two pair of flood gates each; each sluice 4 m. wide, 3.80 m. deep below A. P.

An important work is now in course of construction, to protect the water-way outside the embankment at Schellingwoude. The condition of the open Y east of the dam at Schellingwoude has undergone great changes through the construction of this bar. The new enclosed Y and the Wykermeer behind it formerly served as a large basin filling and emptying itself regularly at every tide, and in that way causing see-sawing currents powerful enough to maintain in front of Amsterdam and eastward alongside the northern shore as far as the Durgerdam lighthouse a channel of considerable width and depth. This process having ceased, Amsterdam consequently has been relieved of the great trouble caused by the deposits of silt in its harbors and docks.

But this silt is now being deposited outside the bar, where it finds a favorable place, and it would, if nothing were done, threaten the navigation from and to Amsterdam across the Zuyder Zee with total destruction. A glance at the hydrographic charts and a mutual comparison of these lead to the conviction that the danger is not an imaginary one. The lines indicating depths of 25, 33 and 50 dcm. below low water should here be considered.

Fig. 1, on Plate VII, represents the state of affairs according to the soundings of 1848, before the construction of the embankment at Schellingwoude had been taken in hand. A vessel leaving Amsterdam for the Zuyder Zee, to sail, for instance, to Frisia, could follow these channels offering a draught of water of 75, 50 and 33 dcm. to a point some distance past the Ydaarn. At this point the broad shallow flat began, marked off on either side by a line indicating depths of 33 dcm., called the "Pampus." After having crossed this shoal, the deep was once more gained.

Fig. 2, Plate VII, represents the state of affairs in accordance with the soundings of 1888. Between the Orange locks and the Ydaarn the depth has considerably decreased, and nowhere is a depth of 33

dm. below low water to be found. A few stray patches of the channel between the Orange locks and the Durgerdam light-tower still have a draught of water of more than 25 dcm. below low water.

The same thing may be seen in Fig. 3, Plate VII, being a chart of very recent date, so that part of the bar under construction has already been represented as finished. The construction of this bar may be considered as the opening of a battle against the elements of Nature, fought for the creation and maintenance of a commensurate channel for navigation stretching beyond the Pampus. The dam or bar extends from the Orange locks to a point opposite the Durgerdam light-tower and is composed of two straight parts connected by a curve of a radius of 2 000 m.

The construction of the bar was decided upon after the fact had been incontestably proved that mere dredging in the open Y could not keep up a stationary depth. A single gale appeared capable of destroying the work performed by the dredgers. Hopes are entertained that when the bar shall have been finished a channel may, without great trouble, be cut and maintained in the north side of it, the dimensions of which have provisionally been fixed at: Bottom width, 225 m.; depth below ordinary low water, 2.6 or 2.7 m. The execution of this subdivision of the work will be delayed, however, until there is a call for it, which is as yet not the case.

The formation of the soil in the open Y is very oozy, as may appear from the details on Plate VII, where Figs. 4, 5, and 6 represent the result of three borings performed in the axis of the bar at distances from the embankment of 1 185, 3 304 and 4 250 m. A stratum of very soft clay, here and there intermingled with fen, sand and shells, reaches to 5 or 6 m. below A. P.; a substratum of considerable thickness of grayish-blue clay reaches to 11 or 12 m. below A. P.; then follows sand, with sandwichings of clay, in which fen is also found here and there, on the whole characterized by the absence of shells. At a depth of 17.5 m. below A. P. pure, fine-grained sand makes its appearance.

In laying down the plan for the bar the oozy nature of the soil had to be kept in view, and many arguments led to the construction simply by means of sand. In the first place, the embankments of the outer harbor of the Merwede Canal had been formed in the same way on a foundation soil naturally possessing many features in common

with that of the projected bar. But, in the second place, it seemed a great advantage to draw upon the ground destined for the fisheries harbor at Ymuiden for the necessary sand. In this way one work accomplished two results.

Concerning the quantity of sand required, great uncertainty prevailed. In consulting the experience gained at the Merwede Canal, as before mentioned, 140 or 150 cu. m. per meter length might be assumed as the quantity required. In order, however, to spare the contractors any risk this uncertainty might give rise to, the contract conditions that a quantity of 600 000 cu. m. of sand is to be reserved for the construction, while, in case more or less should be wanted, compensation would be granted on either side at the rate of 40 cents per cubic meter.

The work was contracted for on December 1st, 1889, the execution was commenced in the spring of 1890. In the beginning things got on all right; according to an observation made at a distance of 500 m. from the embankment it appeared that even less sand was required than had been anticipated. Matters suddenly took a different turn, however, when the bar had advanced to a distance of 2 000 m. from the embankment. The soil proved at that point to be of an uncommonly oozy nature, so that four or five times the quantity of sand originally thought necessary was poured in. The occasion seemed to warrant an inquiry into the bearing of the sand upon the foundation soil. The inquiry was performed by means of borings, the result of which have partly been represented on Plate VII in six cross-sections (Figs. 7–12). In the first two sections, at distances of 500 and 1 185 m. from the embankment, the sand has penetrated to 6 or 7 m. below A. P., and on comparison with the results of the borings, especially of boring No. 1, it appears that the so-called "old" grayish-blue clay is of sufficient stability to bear the weight of the sand bar.

The aforesaid unfavorable section was then reached at, to all appearances, a very deep channel silted up in a later period, and a glance at the cross profiles shows that at a distance of 2 320 m. from the embankment the sand has penetrated to a maximum depth of 22 m. below A. P., where it has found a layer of blue coarse sand and gravel to support it. It should further be observed that in order to allow the sand to penetrate as far as possible into the soil, the bar was

primarily raised to a level of 2 m. above A. P. No finish being given to it before the bar had entirely settled, when the surplus of sand was removed.

At a distance of 2 800 m. from the embankment the stability of the soil increases. The depth to which the sand penetrates is there 11.60 m. below A. P. at the utmost, while the quantity of sand required per meter length has come down to 268 cu. m. Recent calculations have led to the supposition that for the whole bar 900 000 cu. m. of sand will be wanted, *i. e.*, one-half more than the original estimate.

Figs. 13 and 14 on Plate VII show the protection of the crown and slopes as originally designed. The crest reaches to 1.20 m. above A. P., and the cross-section presents the form of a shell. The ground plan of the crown and slopes and berms is altogether 13 m. broad, and as it would have been very expensive to cover this whole area along its entire length (of 4 300 m.) and breadth with stone slopings, another means of protection has been resorted to.

The protection now consists of a puddling of clay covered with rushes strewn with brick rubble underlying a stone rubble; 70 tons of stone will be used per 100 sq. m. Concerning the slopes it has been supposed that in some places the pressed-up soil will form a natural berm, making further protection unnecessary, while on those points where the bottom of the sea is of greater stability, fascines would have to be applied.

With regard to this detail the result fell short of the expectations. Berms of pressed-up matter have indeed been everywhere found, but now that some portions of the bar have during two years been settling down, it appears that the berms either miss the desired height here and there or have been gradually washed away by the surf in rough weather. The foot of the stone-faced berms then loses its support, and falls and shifting are the consequences. The protection at the foot had therefore to be extended.

Two systems of protection have been designed. They may be seen on Plate VII, Figs. 15 and 16, and keep the middle between the two extremes conditioned by the contract.

In looking over these profiles it should be borne in mind, however, that the bar has been represented on these drawings without the changes its settling down is expected to bring about. It is hoped that

the bar will be finished in 1893. Inclusive of the compensation for the additional sand, the cost will amount to about 850 000 guilders.

Another important work in course of construction at Schellingwoude is the building of a new drainage machine to be substituted for the present one. This machine will have to contribute to the maintaining of the level adopted for the North Sea Canal. For a part this is done by sluicing through the locks and by sluices at Ymuiden and at Schellingwoude. At Ymuiden this operation is a great nuisance to trade, a nuisance which will not disappear even when the new tide-lock shall be ready.

At the Orange locks the opportunity for letting out water is quite rare owing to the little difference between flood and ebb tide (on an average the former reaches to 0.074 m. above A. P., the latter to 0.31 m. below A. P.). This is especially the case when it is most wanted. Through the influence of weather and wind the Zuyder Zee level may sometimes be kept very high. It has been observed, for instance, that from 1882 till 1887 the average level of the sea at that point reaches 0.41 and even to 0.60 m. above A. P., during periods of four days and nights, under the said circumstances. During the very rare storm tide of December 12th to 16th, 1883, it reached 0.80 m. above A. P.

The quantity of water which may be discharged into the canal varies between 4 000 000 and 7 000 000 cu. m. per 24 hours. According to observations made in 1889, a year which may be called rather unfavorable, the increase of water per 24 hours may amount to 5 908 800 cu. m., and consequently the increase of level of the enclosed Y, covering an area of 1 020 hectares, amount to 0.58 m.

The present drainage machine at Schellingwoude possesses three horizontal turbines, each driven by a separate steam engine, improved in 1886 to 200 I. H. P. During the testing of one of the machines in May, 1887, at a difference of level of 0.43 m., the number of revolutions of the water-shaft per minute was 56.4, and the discharge 491 cu. m. per minute, corresponding to 46.9 H. P., so that the efficiency appeared to be $\frac{46.9}{200}$, or 23 per cent. Consumption of fuel during the testing, 7.5 kg. per hour and per horse-power water lifted, an unfavorable state of things, chiefly owing to the fact that for small lifts turbines are not to be preferred.

At a difference of level of 0.85 m., a common occurrence, when the service of the machine is chiefly required, it can discharge per 24 hours 1 075 000 cu. m. of water, equal to a decrease of level of the North Sea Canal of 10 cm.

The drainage machine now under construction will be 300 H. P., and at a difference of level of 0.85 m., will be able to produce a decrease of level of 22 cm. in 24 hours. The usually small lift here required fixed the choice of apparatus on paddle-wheels. The only fit site for the machine was the space now chosen near the embankment, between the Orange locks and the point of issue of the bar in the open Y now under construction. It is estimated that 577 I. H. P. will be necessary for an efficiency of 300 H. P. water lifted. The number of wheels has been fixed at six, their diameter at 8.5 m., their breadth at 3 m. Immersion 1.55 m. at a level of 0.3 m. below A. P.

On July 30th, 1891, a contract was made for 149 500 guilders, for the building, fitting and maintenance of the engines, the boilers and the paddle-wheels, for a drainage machine at Schellingwoude belonging to the North Sea Canal works. These works are in course of construction. The principal arrangements will be as follows: Two compound engines, having high pressure cylinders 0.62 m. diameter, and low pressure 1 m. diameter by 1.3-m. stroke. Number of indicated horse-power, 289 per engine. There will be six boilers 10 m. long and 2.2 m. in diameter, Cornish system, with internal stoking spaces and Galloway tubes. The proportion of the number of revolutions of the water-shaft to that of the revolutions of the main shaft is 1 to 10, effected by double-tooth wheel-gear. Consumption of steam under normal circumstances, 7.5 kg. per indicated horse-power per hour. Consumption of fuel 1 kg. (of Ruhr coals) per 9.5 or 10 kg. of steam. Efficiency of the machine under average expansion is 300 H. P. water lifted by the wheels from a canal level of 30 cm. below to a sea-level of 0.85 m. above A. P.

While these engines and wheels are constructing at the factory, a sand dumping has been carried out on the site the drainage machine is to occupy in the enclosed part of the Y, in order to improve the foundation soil. This was finished at the end of June, 1892, and cost 72 600 guilders.

On Plate VIII, Figs. *a* to *f*, has been represented the depth to which

the sand has penetrated and pressed away the clay. In order to prevent these borings from causing springs which might afterwards seriously impede the construction of the engine-house, the boring tubes have been left in the holes, and been filled up with Portland cement mortar after the operation.

On July 21st, 1892, the foundations of the engine-house, here referred to, as they were to be laid on the improved soil, were contracted for. The work will cost 89 430 guilders, and is now in course of execution. The chief conditions of the contract are the laying of 2 500 sq. m. of flooring, by means of timbers supported by about 2 200 piles, the top of the floor reaching to 2.72 m. above A. P.

In a short time the building of the engine-house itself will, in all probability, be contracted for.

Plate VIII gives the ground plan as it was designed in connection with the works already in course of execution, together with a front view in perspective, as it was provisionally designed for the building to be erected on this plan.

In order to give an insight into the importance to navigation of the North Sea Canal, a statistical table is given below concerning the traffic through the North Sea locks, and through those at Schellingwoude.

Year.	Number of sea-going vessels having passed the Ymuiden locks in both directions.	
	Number.	Tonnage (cubic meters).
1877.	3 376	2 283 305
1878.	3 242	2 516 310
1879.	4 013	3 008 694
1880.	4 495	3 393 109
1881.	4 603	4 590 321
1882.	4 674	5 175 695
1883.	5 590	5 437 291
1884.	5 435	5 932 362
1885.	5 811	5 962 657
1886.	5 942	6 253 125
1887.	6 256	8 214 732
1888.	6 859	8 653 521
1889.	6 794	8 891 011
1890.	7 752	9 428 112
1891.	8 149	10 227 504
1892.	8 043	10 485 138

Years.	Number of sea-going vessels and river craft having passed the Schellingwoude locks in both directions.		
	Sea-going vessels.		River craft.
	Number.	Tonnage (in cubic meters).	Number.
1884.	120	56 451	84 509
1885.	104	50 668	85 928
1886.	67	38 170	85 172
1887.	56	27 260	89 437
1888.	41	20 950	77 638
1889.	33	13 946	84 709
1890.	20	4 577	79 766
1891.	14	6 577	106 818
1892.	17	3 181	94 063

Canal and Harbor Dues.

From the beginning different dues have been levied on the North Sea Canal, viz., harbor dues, canal dues and stage dues.

These dues have been for the most part abolished by virtue of an agreement drawn up between the State of the Netherlands and the municipal authorities of Amsterdam, Zaandam and Westzaan, ratified by the law of June 28th, 1890.

According to these agreements the Government canal and harbor dues were, dating from July 1st, 1890, abolished for ships bound for or coming from the said places, while the levying of stage dues of those ships was also suspended.

Sea-going vessels or steamers bound for Amsterdam, Zaandam or Westzaan are therefore exempt from all dues.

Appendix.

I.—Dutch measures compared with American and English:

a. Measures of length: Meter (1 000 mm., 100 cm., 10 dcm.) 3.28 ft.

b. Measures of area: Square meter (1 000 000 sq. mm., etc.) 10.76 sq. ft.; hectare, 107 641 sq. ft.

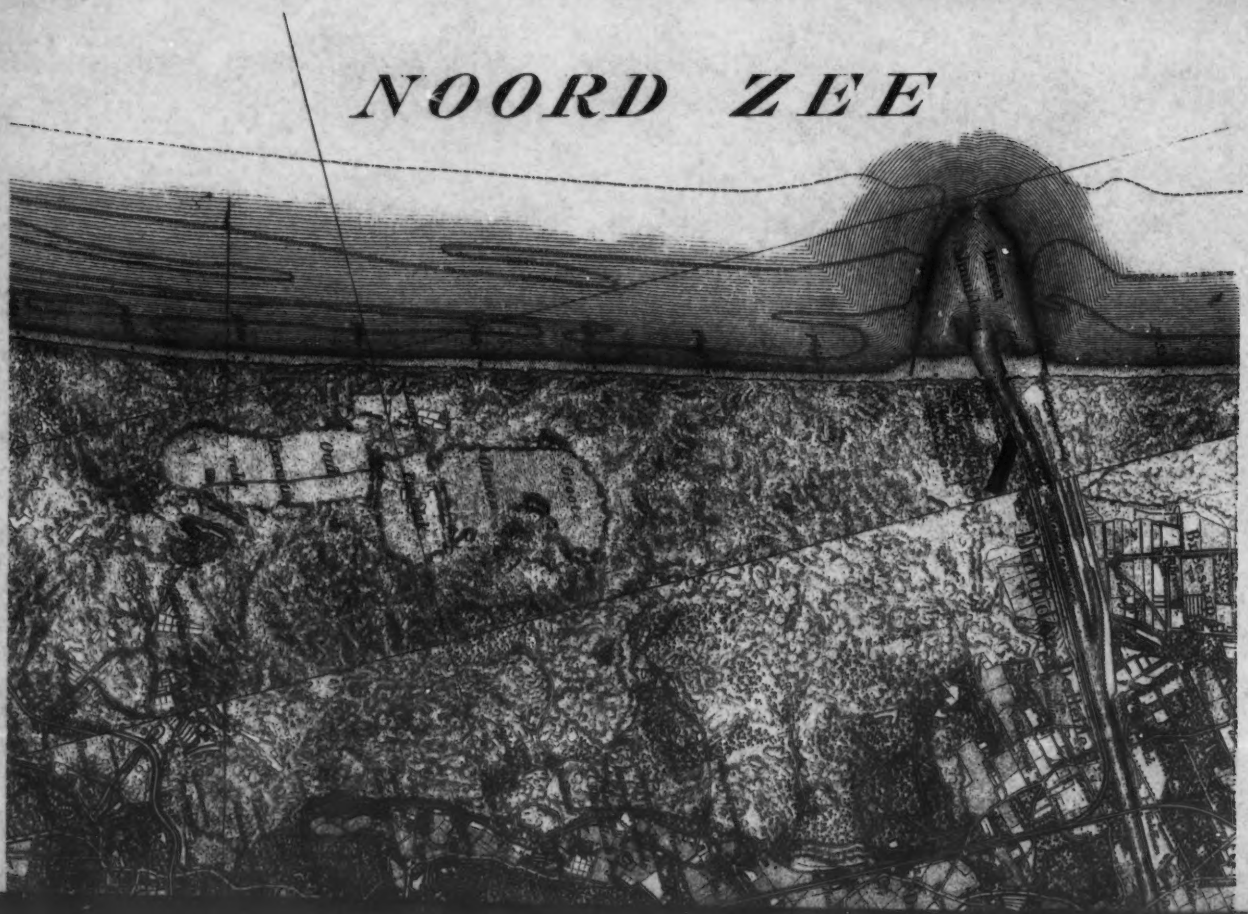
c. Solid measures: Cubic meter (1 000 000 000 cu. mm., etc.) 35.31 cu. ft.

d. Measures of weight: Kilogram (1 000 gm., 100 dkg., 10 hg.) 2.20 lbs. avoirdupois; ton = 0.98 ton English.

II.—Dutch money compared with American and English:

Guilder (100 cents) = about $0.40 = 0.08 £.

Cent = about 0.40 American cent = 0.00083 £.

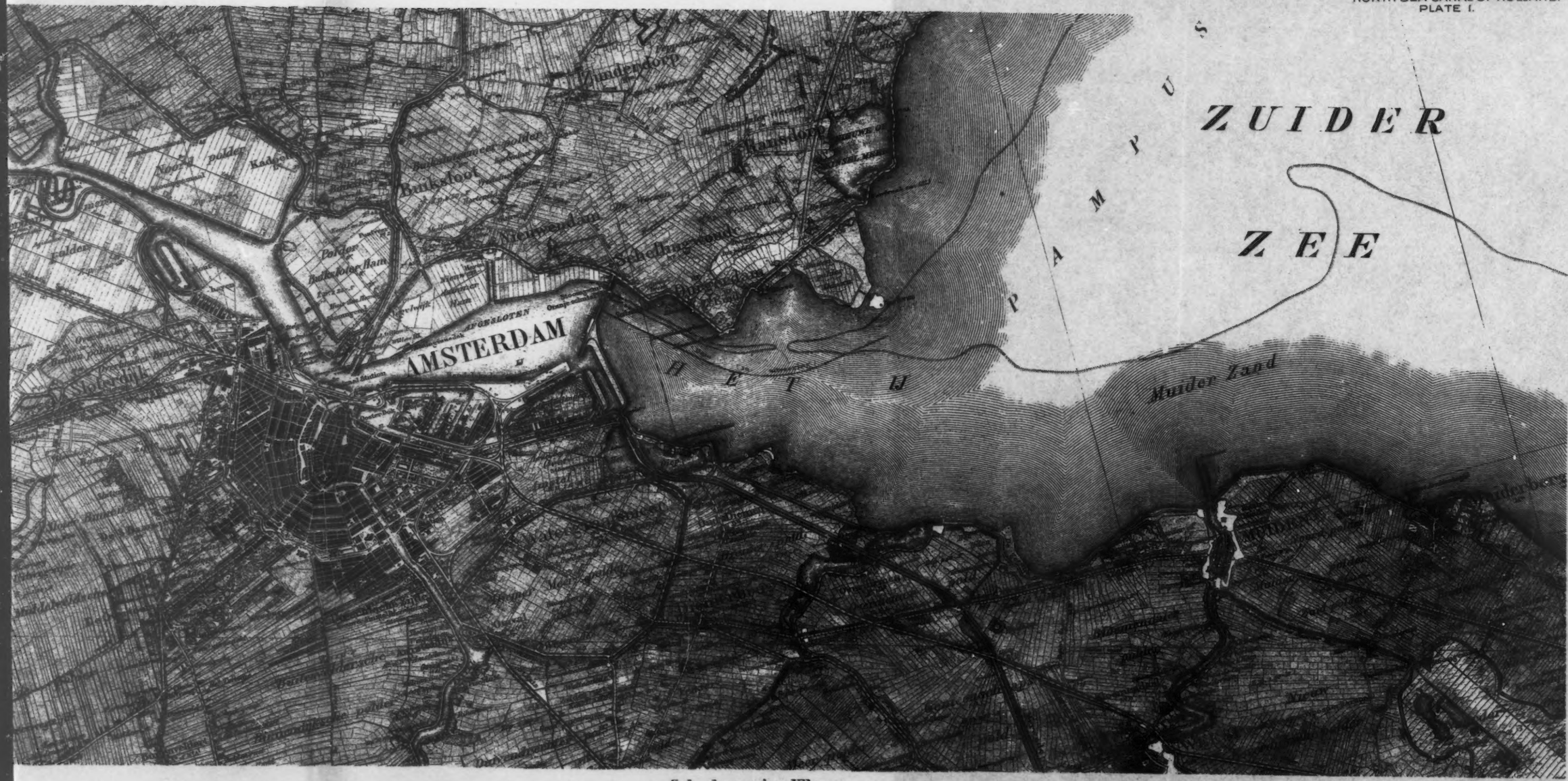

NOORD ZEE

Velsen
Zaandvoort
Selwerden
Spaarnwoude
HAARLEM

polder
Westzaner
polder
Groote M
polder
polder
polder
Buuda polder

Houtrak
polder
Groote M
polder
Sloterdijk
Noorder polder
Kadijk
Buiksloot
Nieuwendam
Schellingwoude
AMSTERDAM
IJ
E T
Schaal van tien Kilometers

VOL. XXX, No. 652.
TRANS. AM. SOC. CIV. ENG'RS.
KEMPEES ON
NORTH SEA CANAL OF HOLLAND.
PLATE I.



NOORDZEE KANAAL

Zee-Haven te Ijmuid

Samenstelling en Bouw van het Noordere Hav

Eerste samenstelling in September 1867.

fig. 1

Eerste wijziging in 1868.

fig. 2

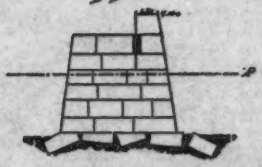
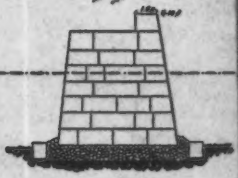


fig. 3.

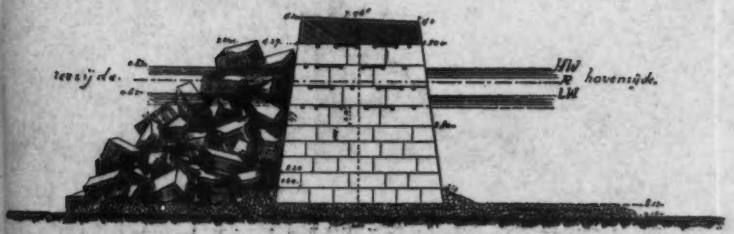


Vernieling door den stormvloed van 2 December 1867.

fig. 3

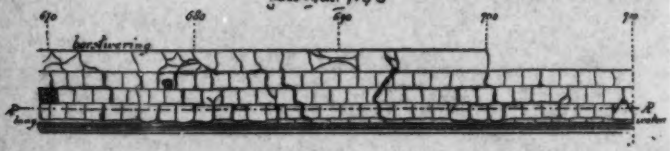
Samenstellingen Bouw sedert 1873.

fig. 4.



Noordere Havenhoofd van 670 tot 710 M. uit den Duinvoet in Z

Zee-zijde. fig. 8



NORTH SEA CANAL

nte IJmuiden.

het Noorder Havenhoofd.

Wijziging in 1869 tot 1872.

fig 3.

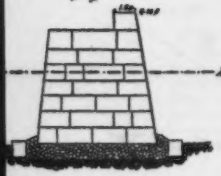
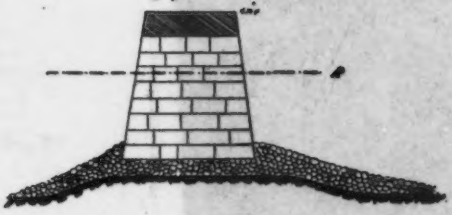
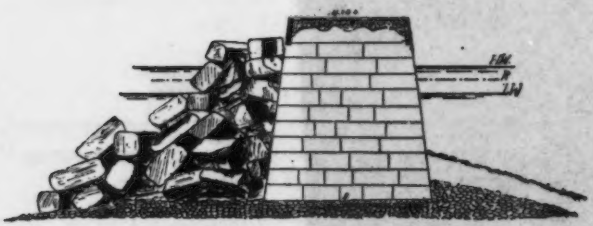


fig 4.

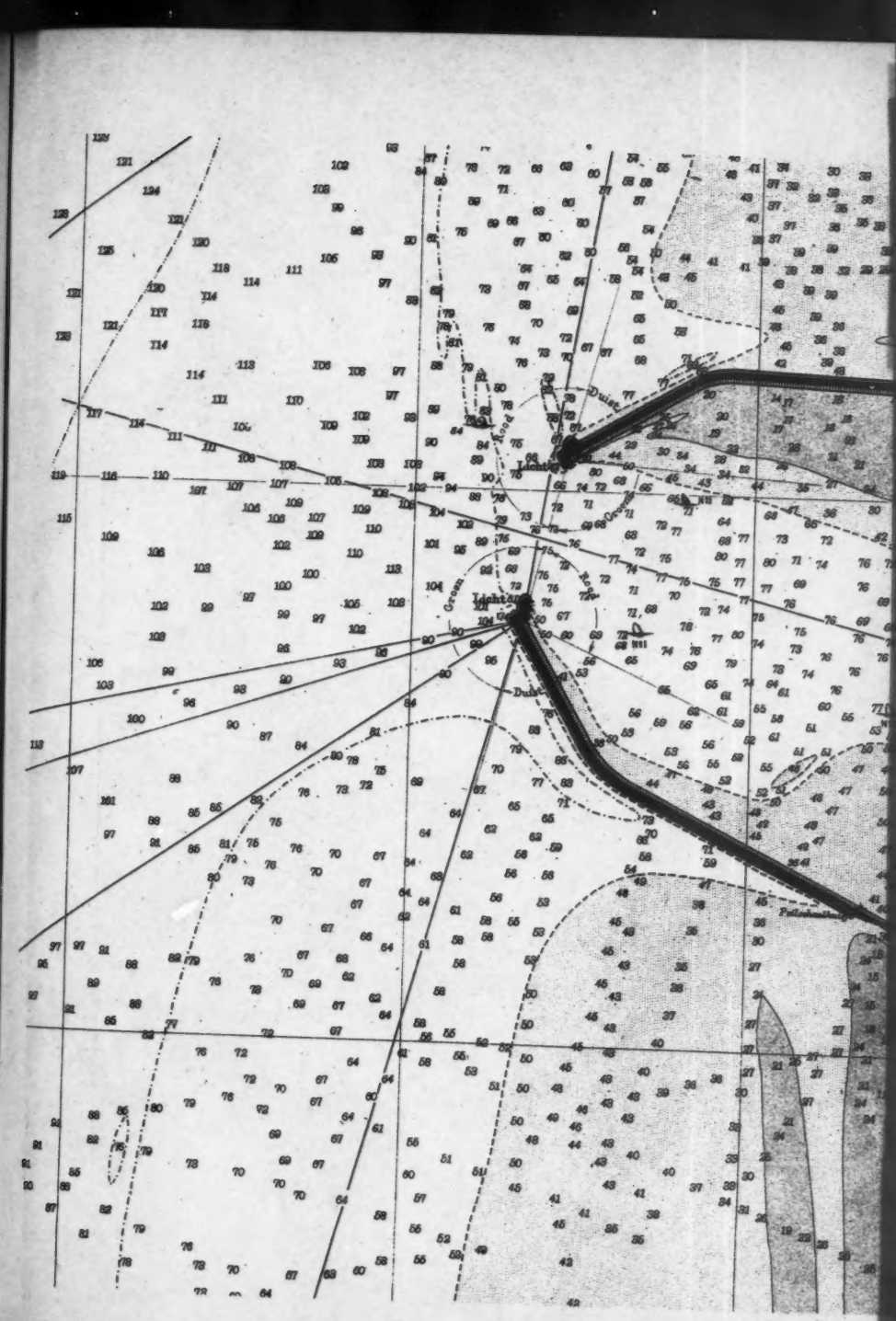


Herstelling van de kruin der Hoofden.
fig 7

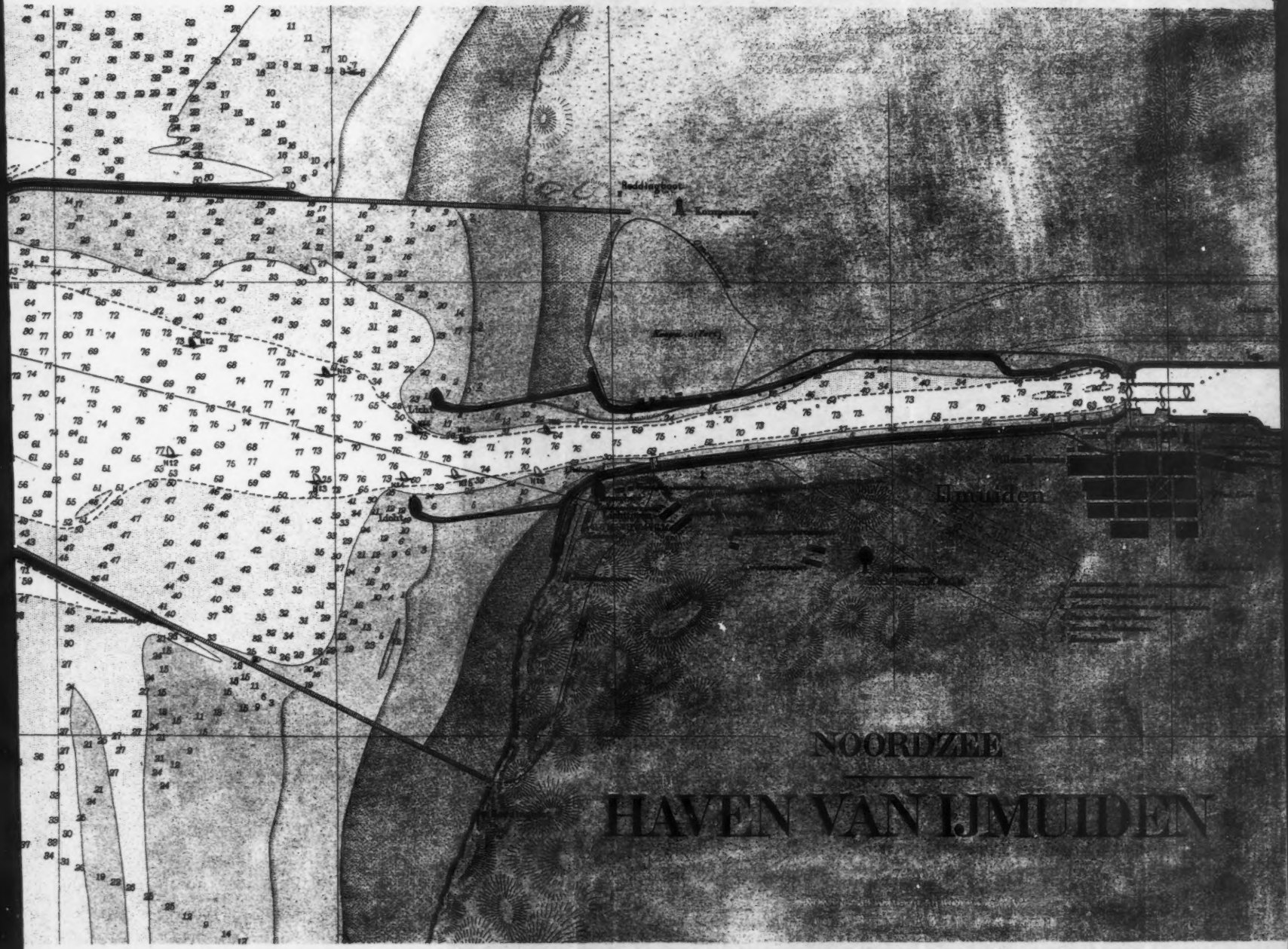


N uit den Duinvoet in Mei 1872.

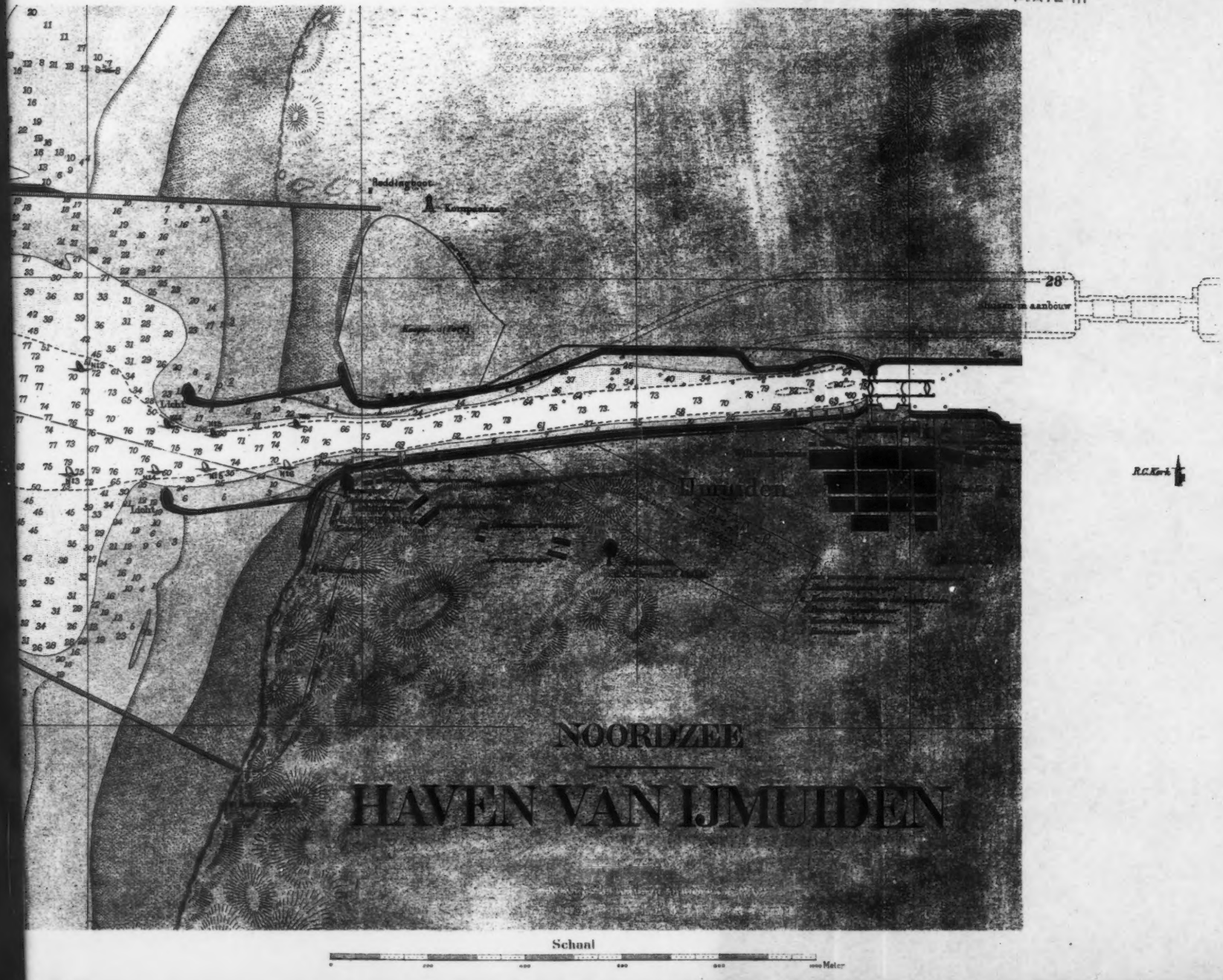
Haven-zijde fig 9.



TRANS.
KE
NORTH SEA



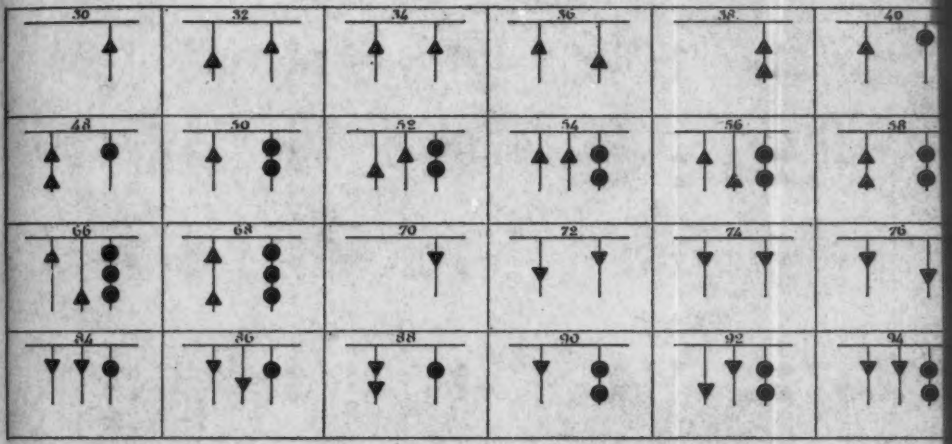
TRANS. AM. SOC. CIV. ENGRS.
KEMPEES ON
NORTH SEA CANAL OF HOLLAND.
PLATE III



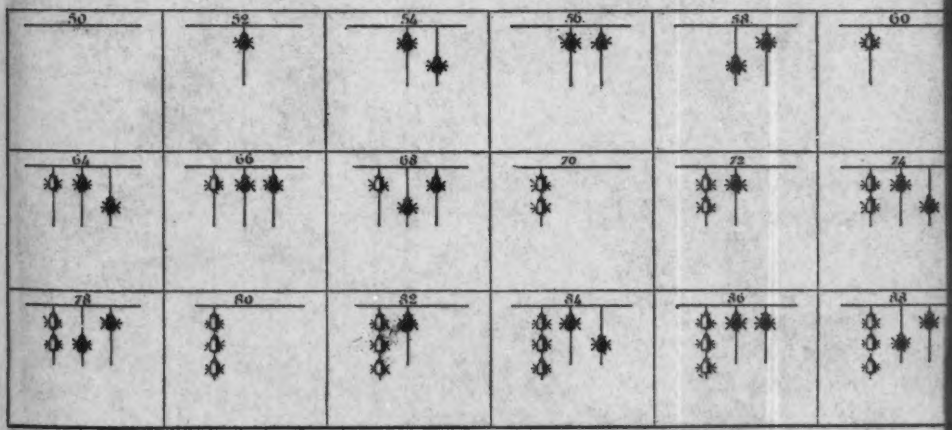
NOORDZEE KANAAL

Getij Seinen
Water Signals

Bij dagmet zwarte ballen en kegels (uit ze
Day Signals. Black balls and cones (as viewed from



Bij nacht met witte en groene lantaarnlichten (uit ze
Night Signals. White and green lights (as viewed from

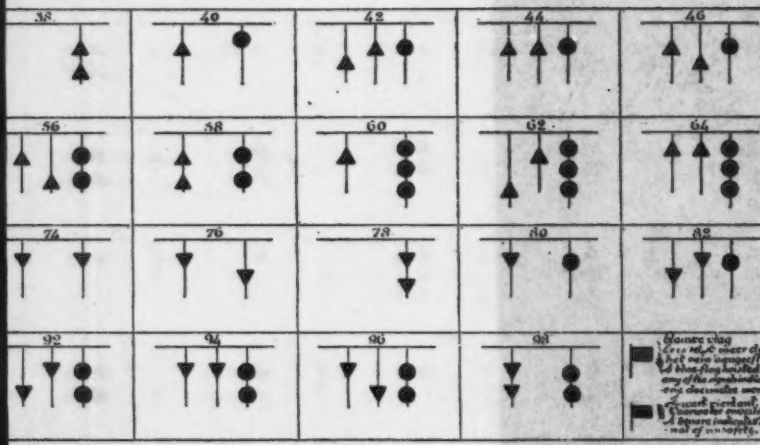


VOL. XXX, No. 652.
TRANS. AM. SOC. CIV. ENGRS.
KEMPEES ON NORTH SEA CANAL OF HOLLAND.
PLATE IV.

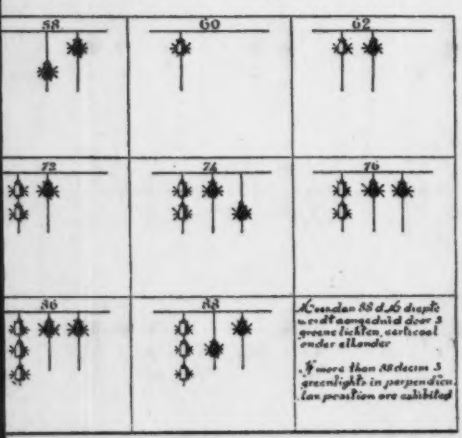
NORTH SEA CANAL

tij Seinen
Later Signals

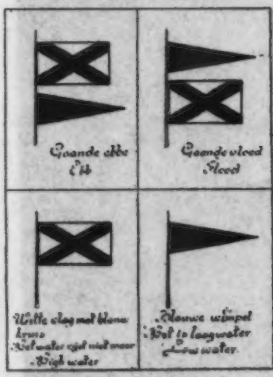
...sen kegels (uit zee gezien)
balls and cones (as viewed from Sea)



...lantaarnlichten (uit zee gezien)
...te and green lights (as viewed from Sea)

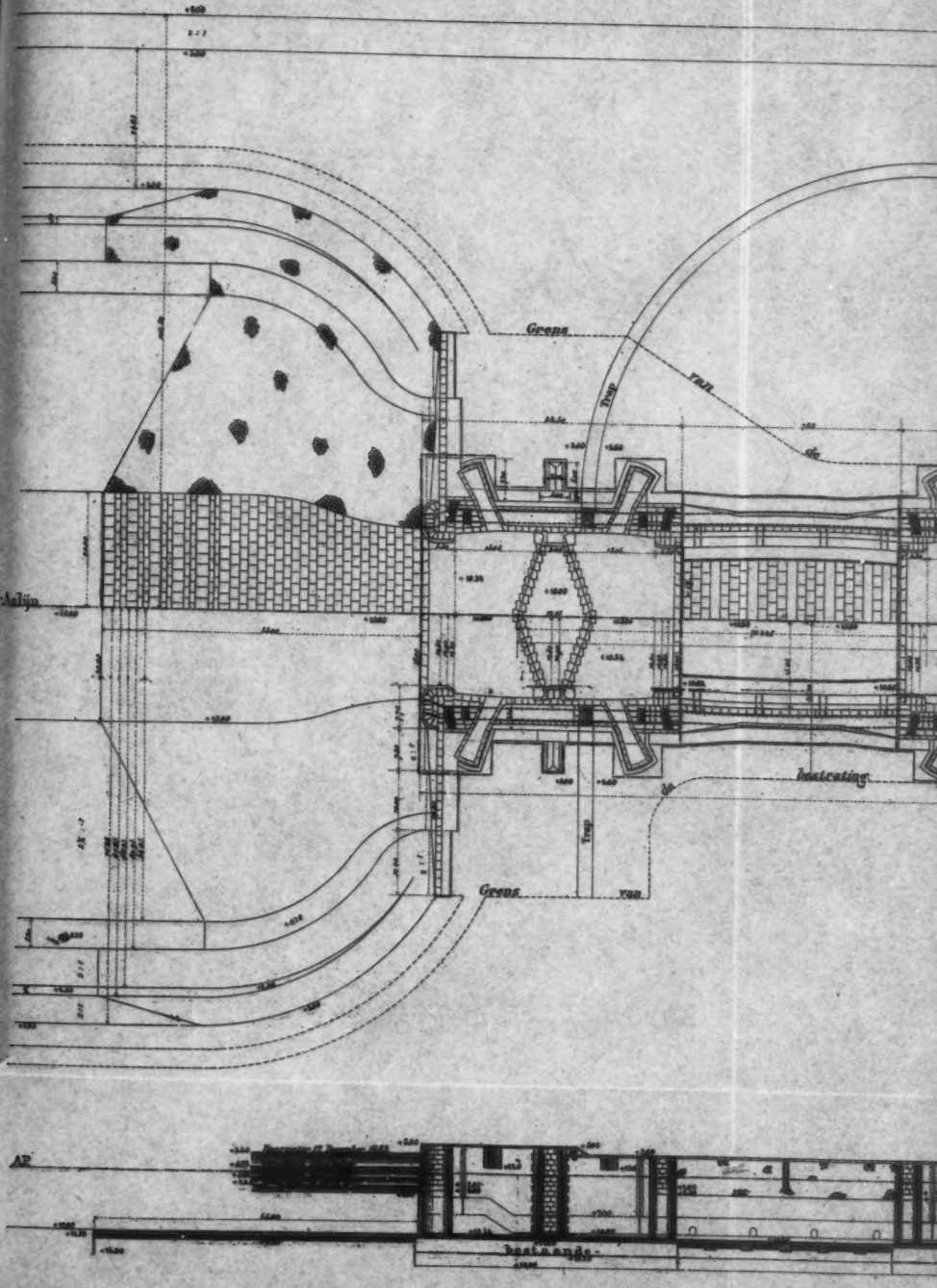


Eb en vloedseinen.
Ebb and Flood Signals

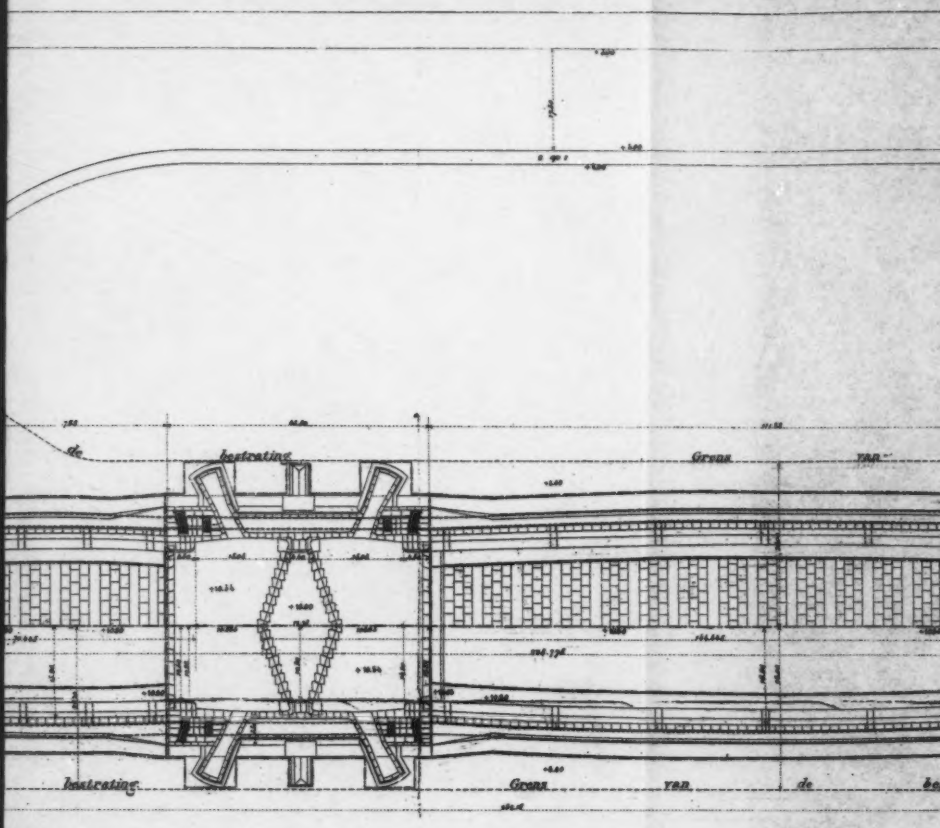


NOORDZEE KANAAL

SCH

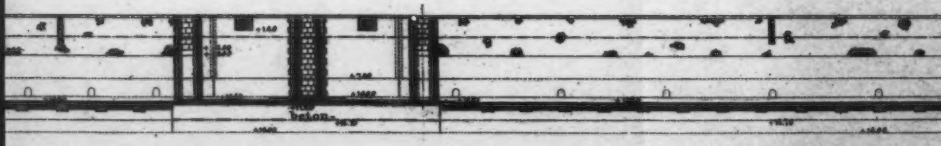


SCHUTSLUIS TE IJMUIDEN.



Plattegrond

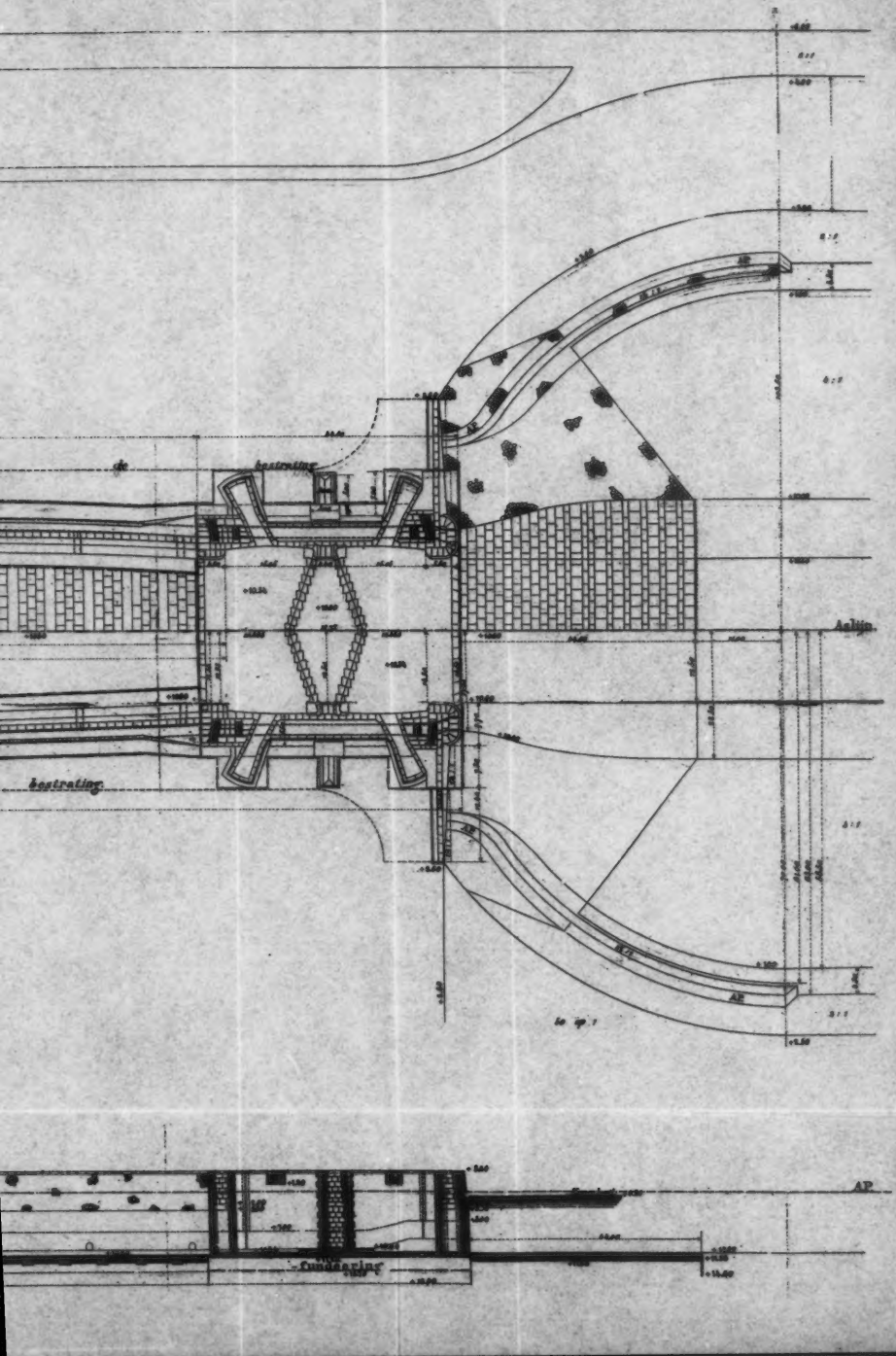
Lengtedoorsnede over de as der sluis.



VOL. XXX, No. 652.

NORTH SEA CANAL

TRANS. AM. SOC. CIV. ENGRS.
KEMPEES ON
NORTH SEA CANAL OF HOLLAND.
PLATE V



NOORDZEE KANAAL

Dwarsprofiller??

FIG. 1. PROFIL VAN AANLEG.

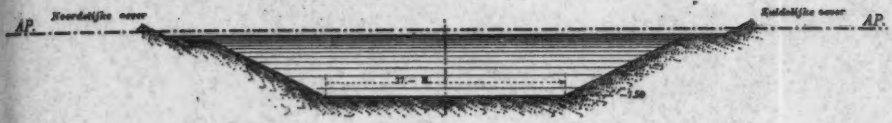


FIG. 2. VAN NOORDZEESLUISEN TOT SIJKANAAL A.

FIG. 3. IN BUITENHUISEN.

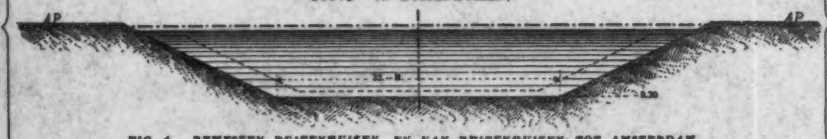
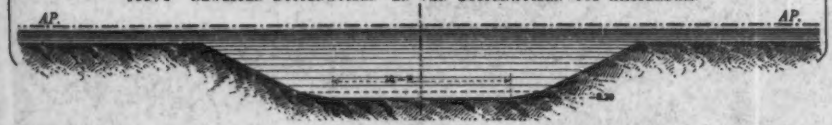


FIG. 4 BEWESTEN BUITENHUISEN EN VAN BUITENHUISEN TOT AMSTERDAM



VOL. XXX, No. 652.
TRANS. AM. SOC. CIV. ENGRS.
KEMPEES ON NORTH SEA CANAL OF HOLLAND.
PLATE VI.

NORTH SEA CANAL

atsprofillen

FIG. 5. VOLGENS MET IN UITVOERING ZIJNDE WERKPLAN (VOLTOOIING IN 1896.)
NORMAAL DWARSPROFIL.

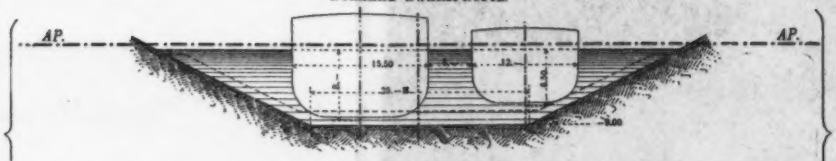


FIG. 6. IN DE WISSELPLAATSEN

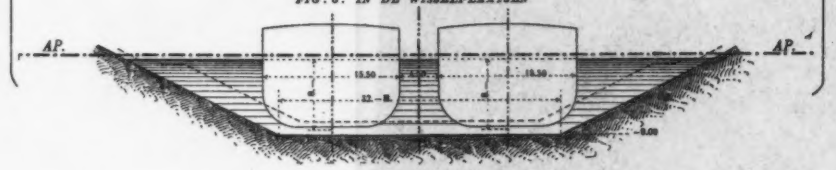
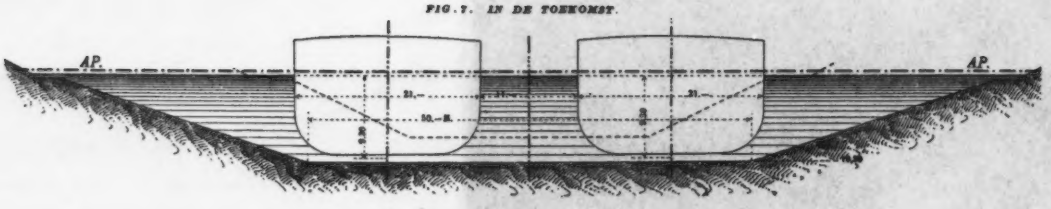


FIG. 7. IN DE TOEKOMST.



NOORDZEE KANAAL

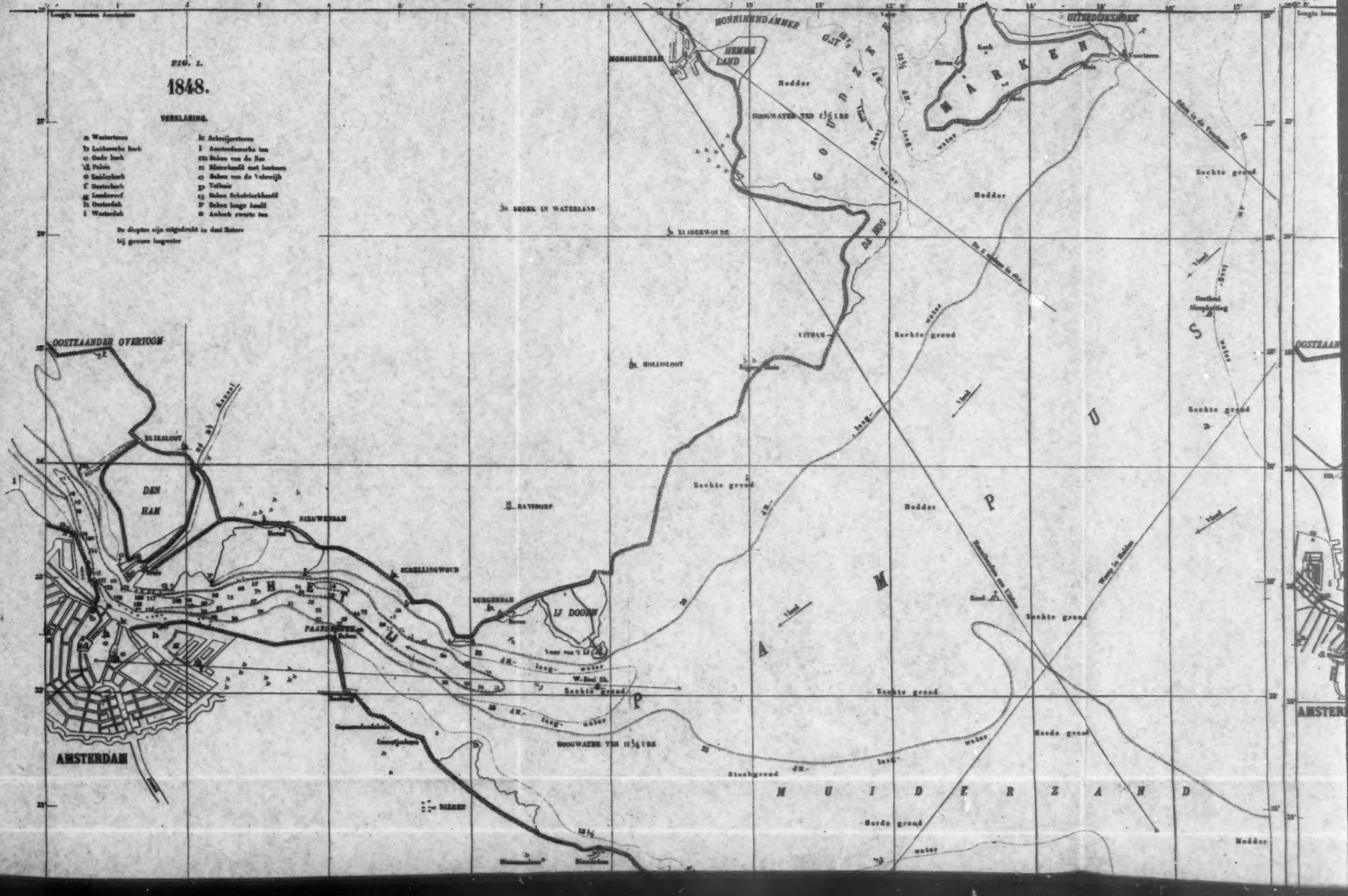


FIG. 1.
1848.
VERKLARING.
a Watertoren
b Luthersche kerk
c Oude kerk
d Paleis
e Zuiderkerk
f Oosterkerk
g Landswerf
h Oosterdok
i Westerdok
k Schreijerstoren
l Amsterdamsche tm
m Balen van de Sas
n Blaterhoofd met lantaren
o Balen van de Veluwijk
p Veldwin
q Balen Scheirinkhoofd
r Balen lange hoofd
s Anker zwarte ton
De diepten zijn uitgedrukt in deci Meters bij gemen laagwater
MONNIKENDAMMER
HEMMELAND
MONNIKENDAM
UITDIJKSDORP
MARKEN
GOUDZEE
DE MOS
OOSTZAANDER OVERTOOM
DEN HAM
NIEUWENDAM
SCHELLINGWOUD
DURGERDAM
LI DOORN
AMSTERDAM
MUIDERZAND
Hodder
Zachte grond
Harde grond
Steenground
Uitbaggering
Omstreek Nieuwgatting
Baken in de Veerdam
Baken in de Veerdam
Baken in de Veerdam

Dam in het open Y. bij Schellingwonde.

FIG. 2.

1888.

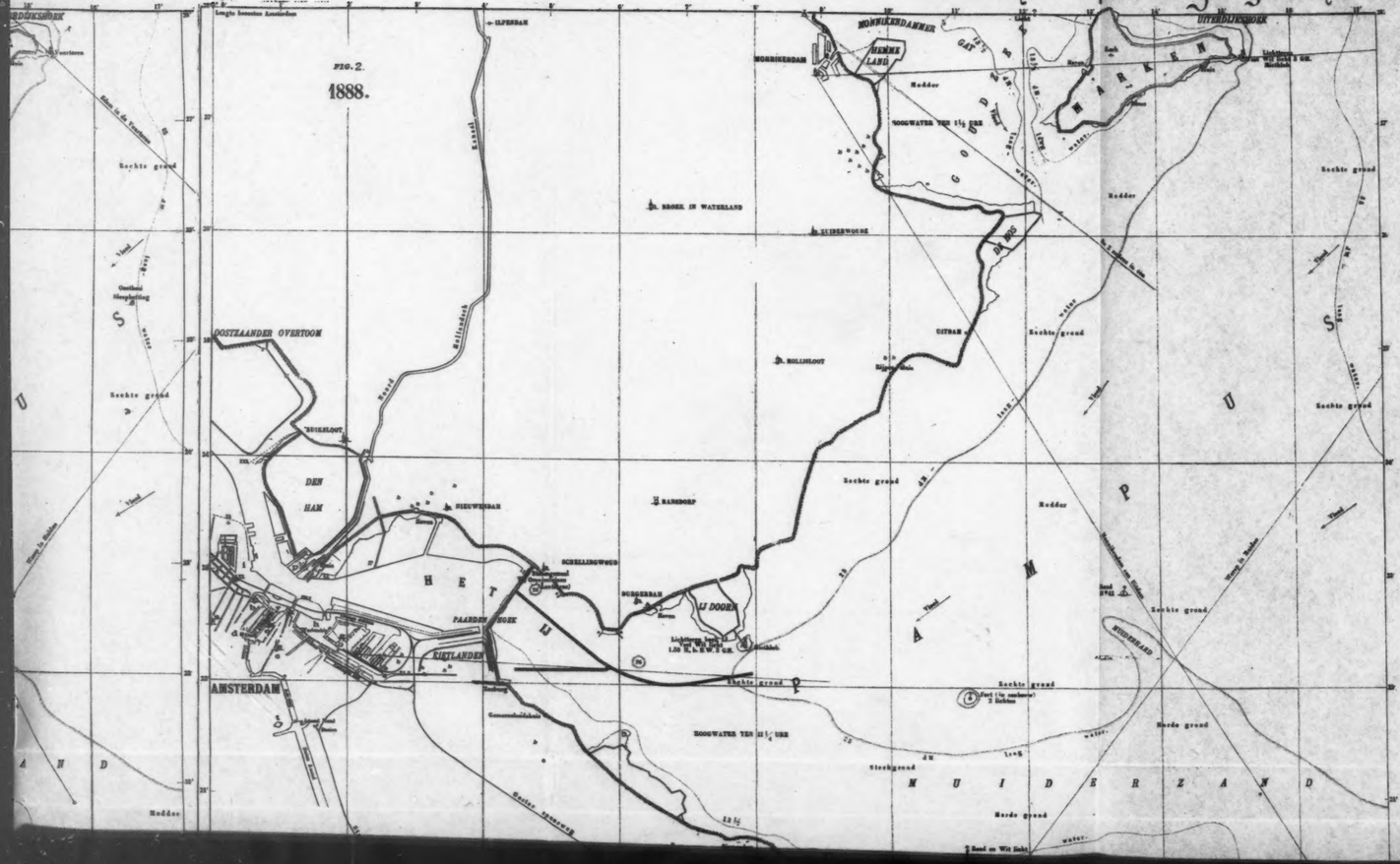
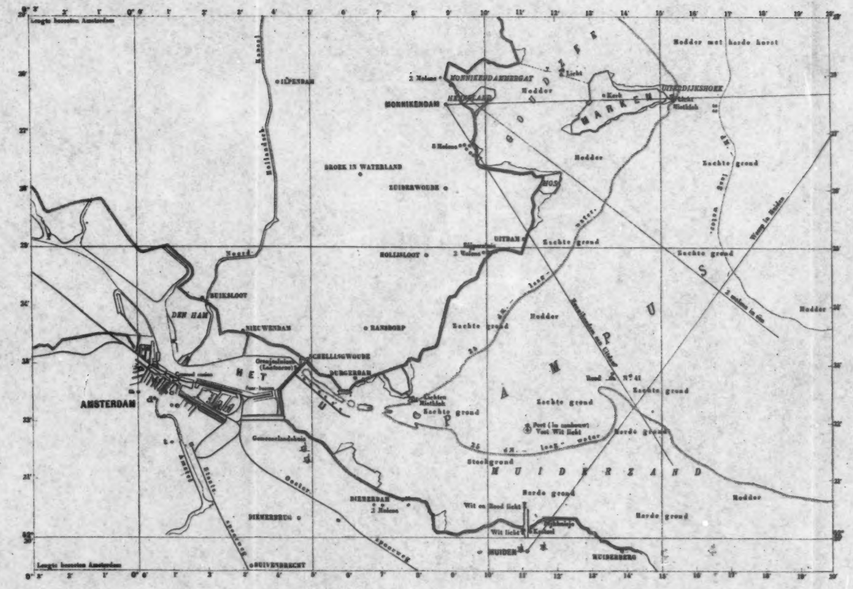


FIG. 3.

1892.



VERKLARING.

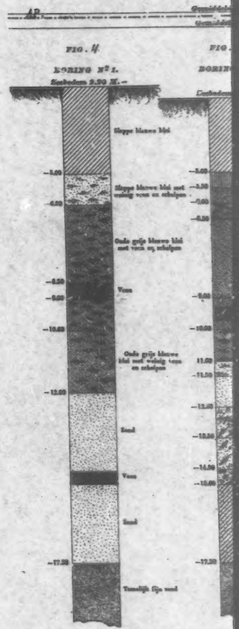
a. Wonderton
b. Lastwerke hoek
c. Serf- Lock
d. Palen
e. Ridderhoek
f. Oosterhoek
g. Loodsroef
h. Westerhoek
i. Westerdok
k. Scheepstimmerwerf
l. Amsterdamsche tm
m. Buiten tm de Nes
n. Muurvierkant met lantaarn
o. Buiten tm de Volewijk
p. Volendam
q. Buiten Schutsluisdijkje
r. Buiten hooge bomlijn
s. Ankerpl. voorste tm
t. Palen voor Volewijk
u. R.C. Kerk

FIG. 4

BORING 1, 2 EN 3 TUSSCHEN 29 JULI EN

VAN DEN TE MAKEN DAM, IJSPECUIEWELIJK

VAN DEN AFSLUITDIJK



VOL. XXX, No. 652.
TRANS. AM. SOC. CIV. ENGRS.
KEMPEES ON
NORTH SEA CANAL OF HOLLAND.
PLATE VII

NORTH SEA CANAL

Profillen volgens het bestek (na zetting)

ngwonde.

FIG. 3.

1892.

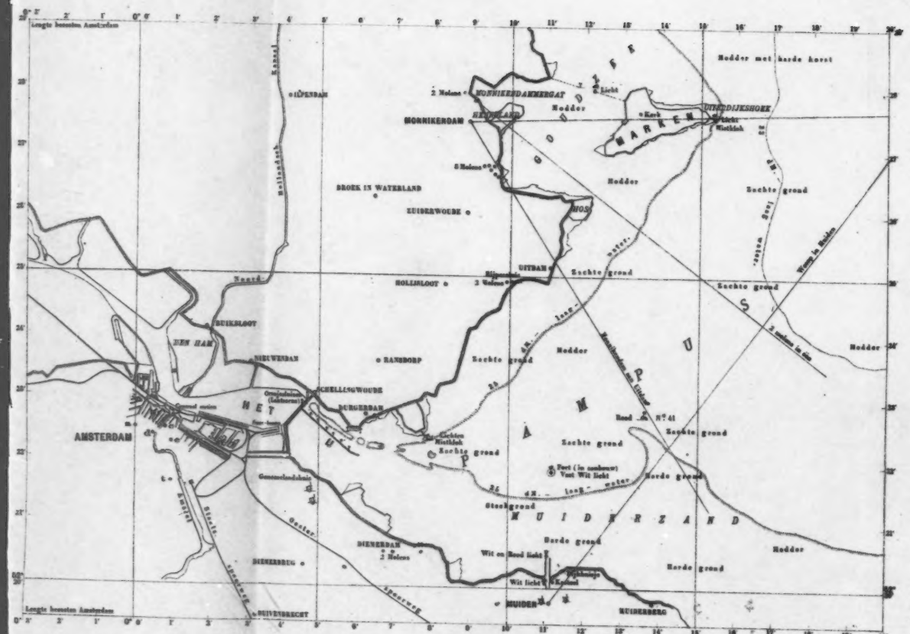

Lengte bovenloo Amsterdam
Lengte benoden Amsterdam
Kanaal
Buikslootsche Vaart
Buiksloot
Den Ham
Nieuwendam
Schellingwoude
Ransdorp
Burgerdam
Amsterdam
Het IJ
Oranjesluizen (Buitensluis)
Noordzeekanaal
Gemeentelandsch
Oosterdok
Schutsluis
Sluisdijk
Oosterdijk
Diemerdijk
Diemerbrug
Diemerdam
Spaarndam
Zeeburg
Zeeburgerdijk
Hollisloot
Uitdam
Broek in Waterland
Zuiderwoude
Monnikendam
Monnikendammergat
Noordeinde
Uitdammerdijk
Uitdammerdijkshoek
Marken
Gouwzee
Ruiterdiep
Gouwzee
Nieuwe Pier
Vuurtoren
Vuurtoren in Marken
Vuurtoren in Uitdam
Vuurtoren in Ransdorp
Vuurtoren in Diemerdam
Vuurtoren in Zeeburg
Vuurtoren in Muiden
Vuurtoren in Huizen
Vuurtoren in Muiderberg
Vuurtoren in Durgerdam
Vuurtoren in Schellingwoude
Vuurtoren in Nieuwendam
Vuurtoren in Buiksloot
Vuurtoren in Den Ham
Vuurtoren in Hollisloot
Vuurtoren in Broek in Waterland
Vuurtoren in Zuiderwoude
Vuurtoren in Monnikendam
Vuurtoren in Uitdammerdijkshoek
Vuurtoren in Marken
Vuurtoren in Gouwzee
Vuurtoren in Ruiterdiep
Vuurtoren in Gouwzee
Vuurtoren in Nieuwe Pier
Vuurtoren in Vuurtoren
Vuurtoren in Vuurtoren in Marken
Vuurtoren in Vuurtoren in Uitdam
Vuurtoren in Vuurtoren in Ransdorp
Vuurtoren in Vuurtoren in Diemerdam
Vuurtoren in Vuurtoren in Zeeburg
Vuurtoren in Vuurtoren in Muiden
Vuurtoren in Vuurtoren in Huizen
Vuurtoren in Vuurtoren in Muiderberg
Vuurtoren in Vuurtoren in Durgerdam
Vuurtoren in Vuurtoren in Schellingwoude
Vuurtoren in Vuurtoren in Nieuwendam
Vuurtoren in Vuurtoren in Buiksloot
Vuurtoren in Vuurtoren in Den Ham
Vuurtoren in Vuurtoren in Hollisloot
Vuurtoren in Vuurtoren in Broek in Waterland
Vuurtoren in Vuurtoren in Zuiderwoude
Vuurtoren in Vuurtoren in Monnikendam
Vuurtoren in Vuurtoren in Uitdammerdijkshoek
Vuurtoren in Vuurtoren in Marken
Vuurtoren in Vuurtoren in Gouwzee
Vuurtoren in Vuurtoren in Ruiterdiep
Vuurtoren in Vuurtoren in Gouwzee
Vuurtoren in Vuurtoren in Nieuwe Pier
Vuurtoren in

FIG. 7. DWARSPROFIL VAN HET SANDPROFIL OP 800 M. UIT DEN VOET VAN DEN AFSLUITDIJK.

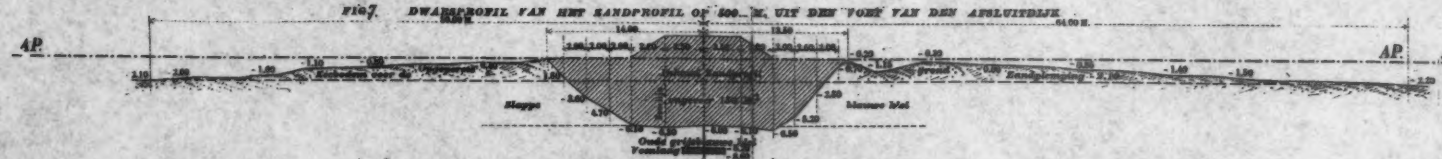


FIG. 8. DWARSPROFIL VAN HET SANDPROFIL OP 1180 M. UIT DEN VOET VAN DEN AFSLUITDIJK.

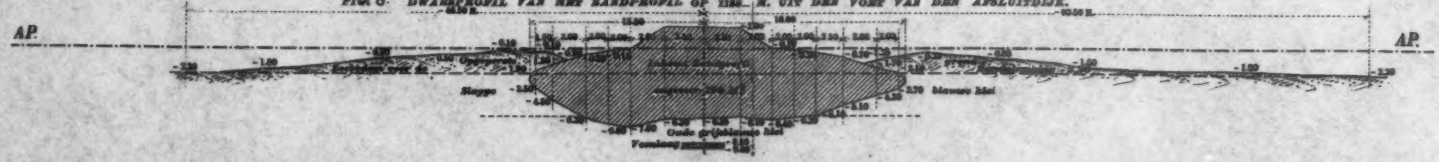
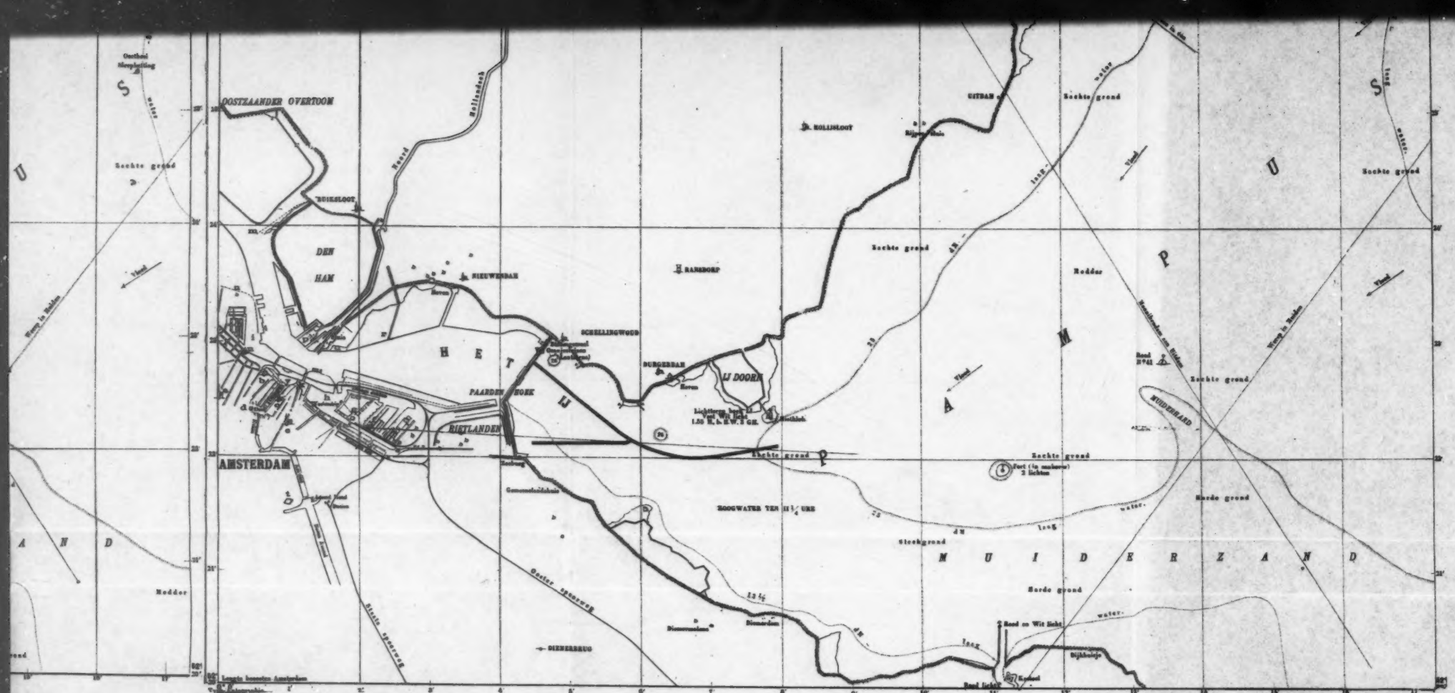


FIG. 9. DWARSPROFIL


OOSTZAANDER OVERTOOM
DEN HAM
HET PAARDEN WOEL
RIETLANDEN
AMSTERDAM
SCHELLINGWOUDE
DURGERDAM
IJ DOORN
NIEUWENDAM
RAMSDORP
ZUIDERZEE
Sluice
Locks
Harbour
Bridge
Sand
Mudd
Soft ground
Hard ground
Stiff ground
Water
Land
Buoy
Beacon
Light
Lighthouse
Church
Windmill
Pier
Quay
Canal
Railway
Road
Tram
Ferry
Boat
Steamer
Sailing vessel
Fishing boat
Anchorage
Depth
Scale
Compass
Wind
Tide
Current
Flood
Ebb
Low water
High water
Spring
Neap
Tidal stream
Direction
Distance
Bearing
Position
Latitude
Longitude
Chart
Survey
Soundings
Fathoms
Feet
Metres
Nautical mile
Knot
Speed
Course
Heading
Variation
Deviation
Magnetic
True
Grid
Datum
Projection
Mercator
Transverse
Conformal
Scale factor
Central meridian
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Origin
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Map
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Plan
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Symbol
Abbreviation
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Caution
Danger
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Restricted
Area
Zone
Boundary
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Extent
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Publication
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Author
Surveyor
Hydrographer
Cartographer
Engineer
Contractor
Client
Project
Job
Drawing
Sheet
Page
Volume
Part
Section
Chapter
Table
Figure
Appendix
Index
Contents
Preface
Introduction
Conclusion
Bibliography
Glossary
Acknowledgements
Dedication
Foreword
Abstract
Summary
Keywords
Publication info
Copyright
Rights
Permission
Reproduction
Distribution
Sale
Price
Order
Delivery
Payment
Invoice
Receipt
Refund
Exchange
Return
Warranty
Guarantee
Liability
Disclaimer
Terms
Conditions
Agreement
Contract
Signature
Witness
Notary
Seal
Stamp
Certificate
Diploma
Degree
Qualification
Experience
Skill
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Ability
Training
Education
Research
Study
Analysis
Synthesis
Evaluation
Application
Implementation
Development
Design
Construction
Maintenance
Repair
Operation
Management
Administration
Organization
Planning
Control
Monitoring
Reporting
Communication
Collaboration
Coordination
Integration
Interface
Network
System
Subsystem
Component
Module
Unit
Element
Feature
Function
Process
Procedure
Method
Technique
Tool
Equipment
Material
Resource
Budget
Cost
Schedule
Milestone
Deliverable
Requirement
Specification
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Regulation
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Risk
Issue
Problem
Solution
Alternative
Option
Decision
Approval
Review
Audit
Inspection
Test
Verification
Validation
Quality
Performance
Reliability
Safety
Security
Environment
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Efficiency
Effectiveness
Productivity
Innovation
Improvement
Change
Version
Release
Update
Upgrade
Patch
Fix
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Warning
Alert
Notification
Message
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Letter
Memo
Report
Presentation
Meeting
Conference
Workshop
Seminar
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Lecture
Tutorial
Exercise
Quiz
Exam
Test
Assessment
Evaluation
Feedback
Survey
Questionnaire
Interview
Observation
Experiment
Simulation
Model
Prototype
Mockup
Wireframe
Flowchart
Diagram
Graph
Chart
Table
Figure
Image
Photo
Video
Audio
Animation
Interactive
Multimedia
Hypertext
Hyperlink
Navigation
Search
Index
Table of contents
Bookmark
Annotation
Comment
Highlight
Underline
Strikethrough
Bold
Italic
Font
Size
Color
Background
Foreground
Alignment
Justification
Indentation
Spacing
Margin
Padding
Border
Shadow
Gradient
Texture
Pattern
Image
Icon
Button
Menu
Toolbar
Dialog
Window
Tab
Scroll
Zoom
Pan
Rotate
Flip
Crop
Resize
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Paste
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Delete
Undo
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Open
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Preferences
Settings
Options
Configuration
Customization
Personalization
Localization
Internationalization
Translation
Language
Dictionary
Thesaurus
Spell check
Grammar check
Style check
Plagiarism check
Citation
Reference
Bibliography
Footnote
Endnote
Appendix
Glossary
Index
Table of contents
Table of figures
Table of tables
List of abbreviations
List of symbols
List of acronyms
List of definitions
List of terms
List of concepts
List of topics
List of subjects
List of keywords
List of authors
List of contributors
List of sponsors
List of clients
List of customers
List of users
List of stakeholders
List of partners
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List of presenters
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List of discussants
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List of leaders
List of coordinators
List of administrators
List of assistants
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List of clerks
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List of operators
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List of engineers
List of architects
List of designers
List of developers
List of programmers
List of analysts
List of testers
List of writers
List of editors
List of proofreaders
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List of printers
List of binders
List of distributors
List of retailers
List of wholesalers
List of importers
List of exporters
List of manufacturers
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List of farmers
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List of fishermen
List of hunters
List of gatherers
List of miners
List of drillers
List of refiners
List of processors
List of packagers
List of shippers
List of receivers
List of warehousers
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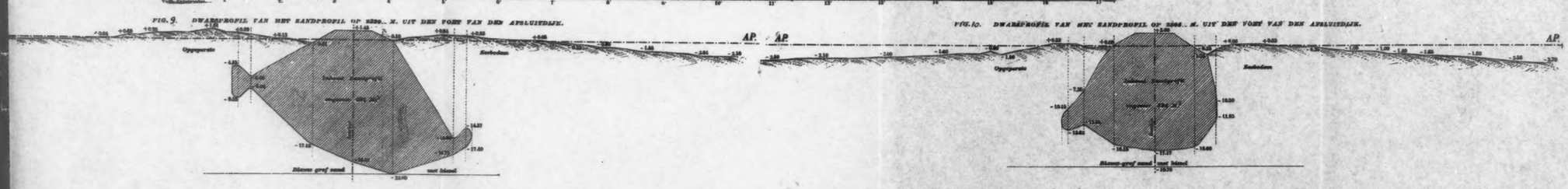
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Blauwe grof zand
met bijmeng

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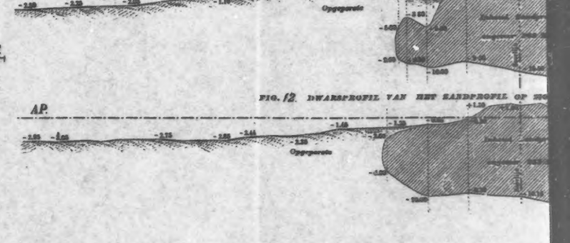
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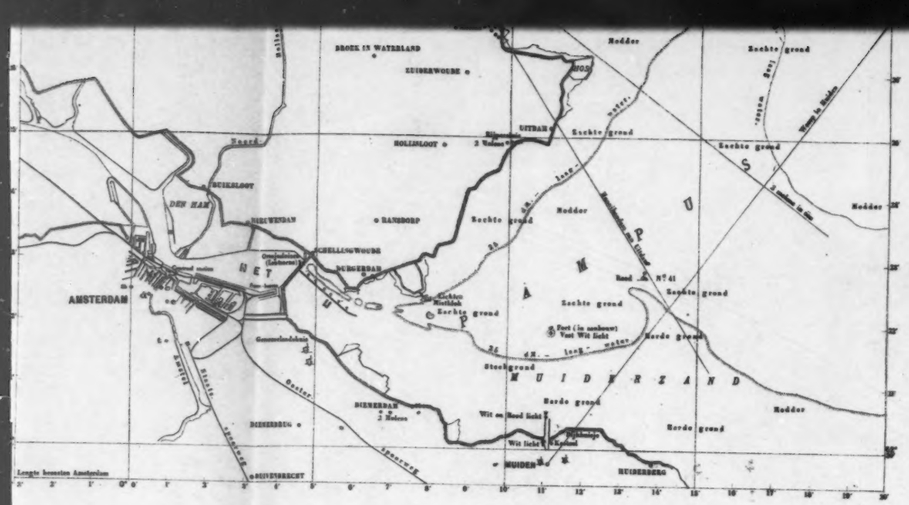
AMSTERDAM
HET
Y
DEN HAM
NIEUWENDAM
RANDDORP
SCHELLINGWOUDE
DURGERDAM
BROEK IN WATERLAND
ZUIDERWOUDE
HOLLENLOOT
UITDAM
Sluis
Buiten Spaarndam
Sluis
Buiten Spaarndam
Noorder Gat
Zuider Gat
Noorder Gat
Zuider Gat
Noorder Gat
Zuider Gat

NOORDZEE KANAAL NORTH SEA CANAL

GRONDBORINGEN TER PLAATSE VAN HET TE BOUWEN STOOMGEMAAL. bij Sa

AANDUIDING DER PLAATS BORINGEN VERRICHT VOOR

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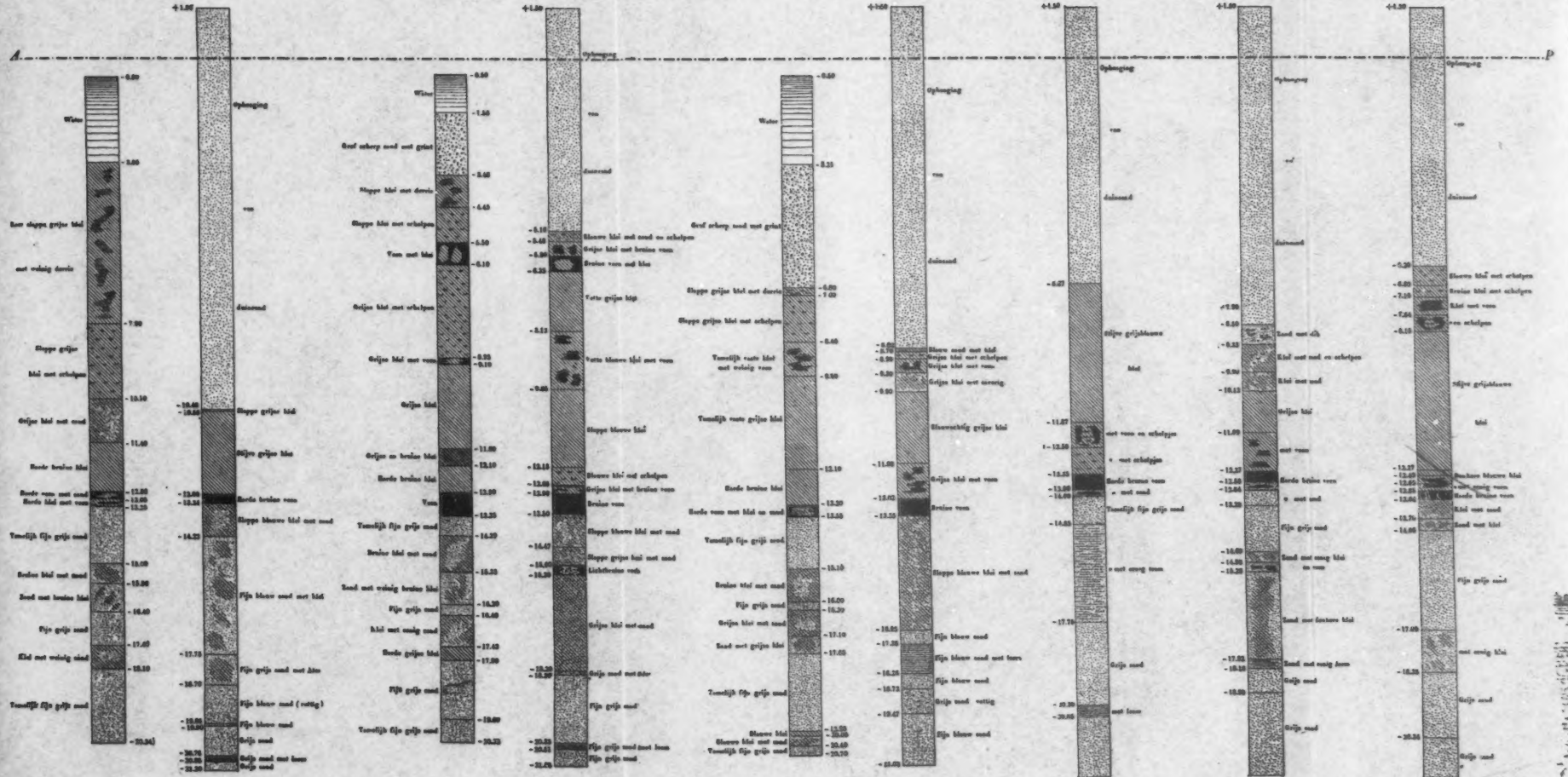

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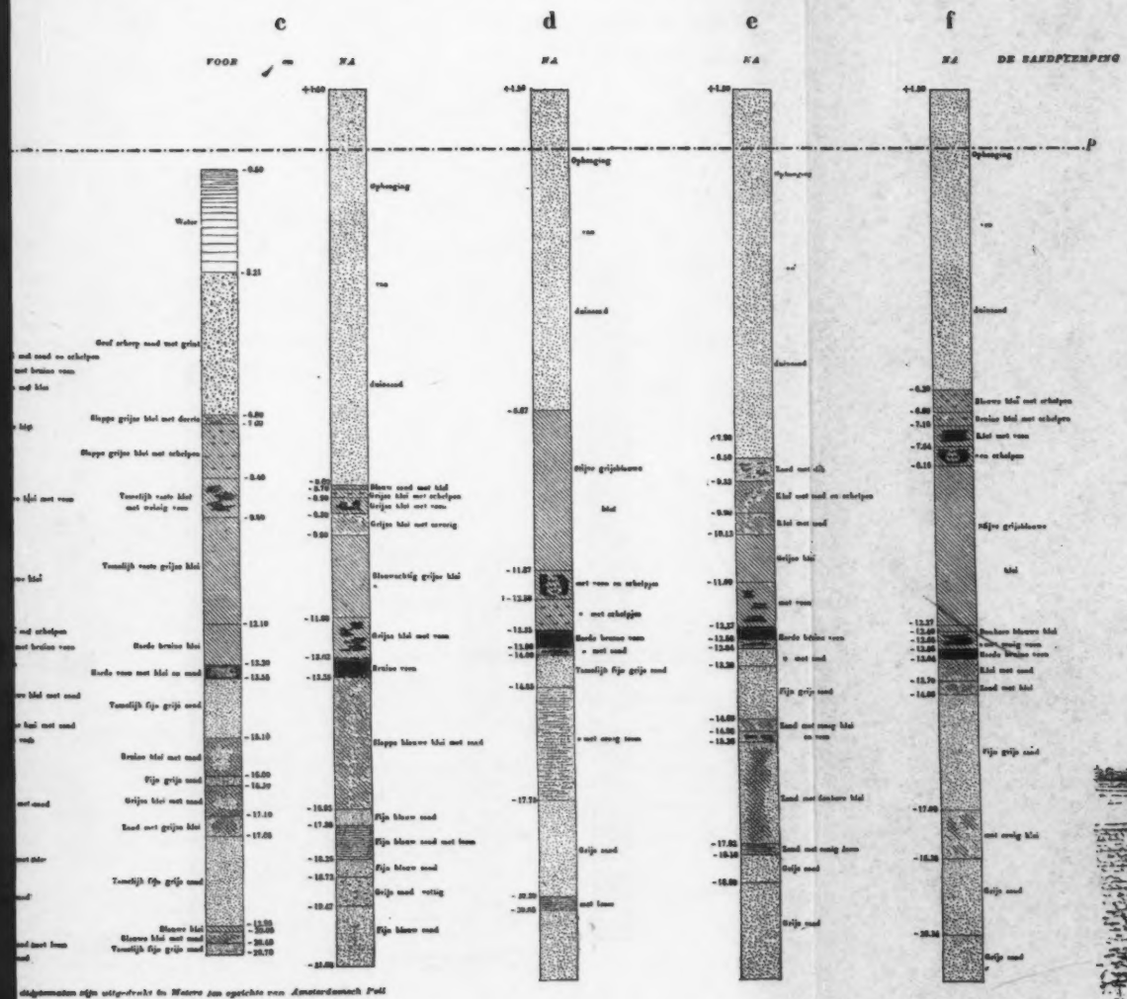
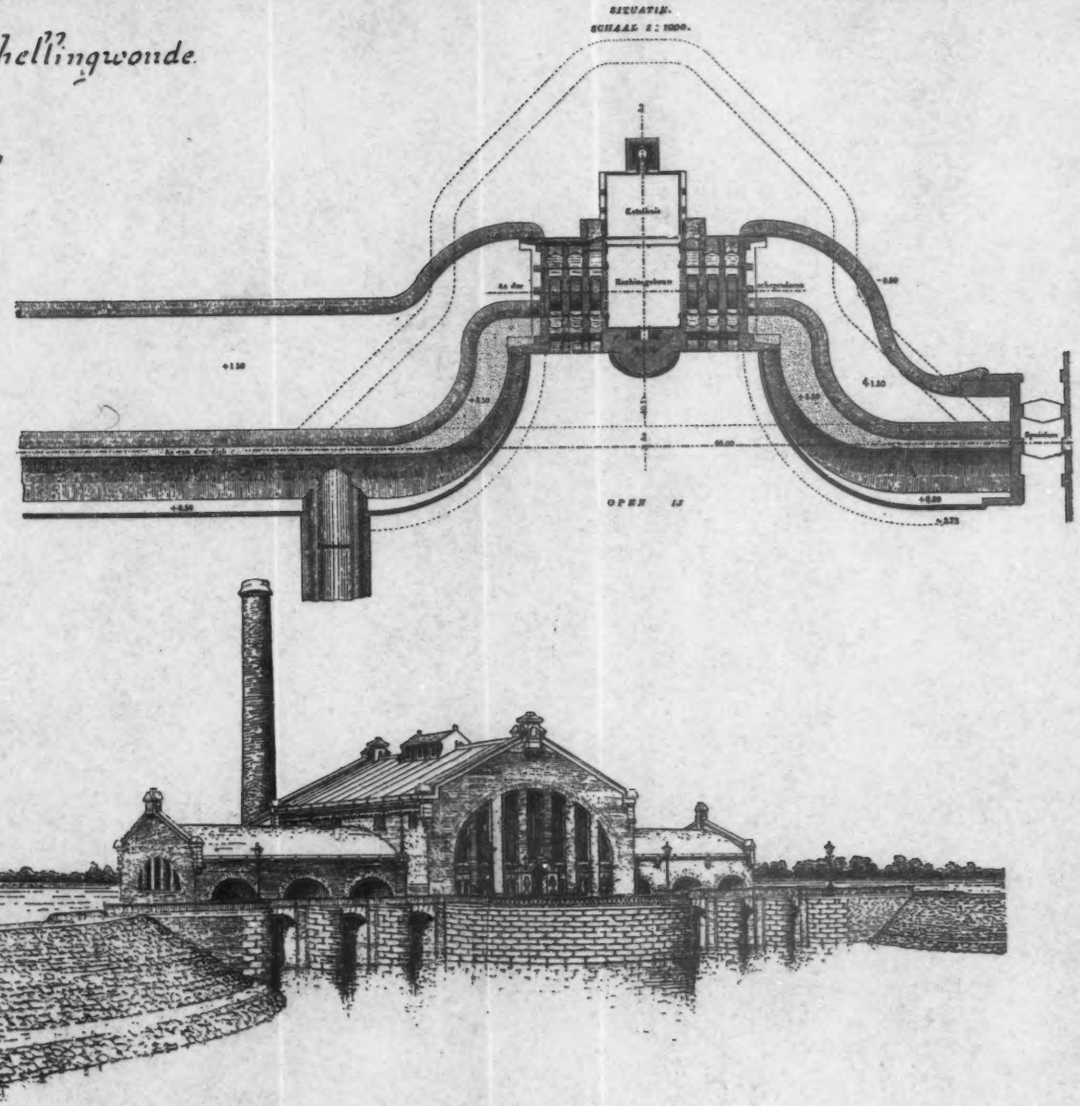
VOL. XXX, No. 652.
TRANS. AM. SOC. CIV. ENGRS.
KEMPEES ON NORTH SEA CANAL OF HOLLAND.
PLATE VIII.

EA CANAL

GRONDBORINGEN TER PLAATSE VAN HET TE BOUWEN STOOMGEMAAL bij Schellingwonde.





List of Plates.

Plate I. Strategical map.
" II. Construction of the piers at Ymuiden.
" III. Hydrographic chart giving a view of Ymuiden Harbor.
" IV. Day and night signals at Ymuiden.
" V. New locks at Ymuiden (in course of construction).
" VI. Cross profiles of the North Sea Canal.
" VII. Embankment bar in the open Y (in course of construction).
" VIII. Steam drainage machine at Schellingwoude (in course of construction).

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653.

(Vol. XXX.—November, 1893.)

NOTES ON PROJECTS FOR THE NORTH SEA CANAL FROM 1629–1893.

By A. HUET, C. E.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

The United Netherlands owed their political independence in the 17th century in a large measure to the prosperity of the Dutch sea trade, which in those times embraced nearly one-half of the European commerce. The chief center of its extensive shipping was the rich city of Amsterdam, capital of the prosperous province of Holland and situated on the south side of a creek or inlet of the Zuider Zee, called the Y. This creek offered, over a short length, a depth of 30 ft., but opposite the city the bottom silted up and the entrance to the creek was barred by a shoal, called Pampus, which hardly offered 10 ft. of water.

To get rid of the mud banks in the port, Burgomaster Hudde in the 17th century invented the mud-dredger, prototype of the

NOTE.—Discussions on all papers presented to the International Engineering Congress will be published simultaneously in the number for December, 1893.

present dredging machines; and the passage of the bar was made possible by the invention of "the ship camel," a kind of floating caisson which was attached to the side of a ship and lifted her over the shoal.

In 1825 a canal of 80 km. length, parallel to the sea coast, was made to connect Amsterdam to the port of Nieuwe-Diep, and some time afterwards sluice docks were constructed to provide for better ship accommodation at Amsterdam. These works proved sufficient in their days, but the advent of steam navigation necessitated the opening of a shorter route to the North Sea.

A series of projects for a canal direct to the coast were made, which resulted in the construction of the present North Sea Canal, with locks on both ends, opened for commerce in 1876.*

First.—The projects from 1629–1823, which were intended to connect the Y to the North Sea for other objects than the commercial wants of Amsterdam.

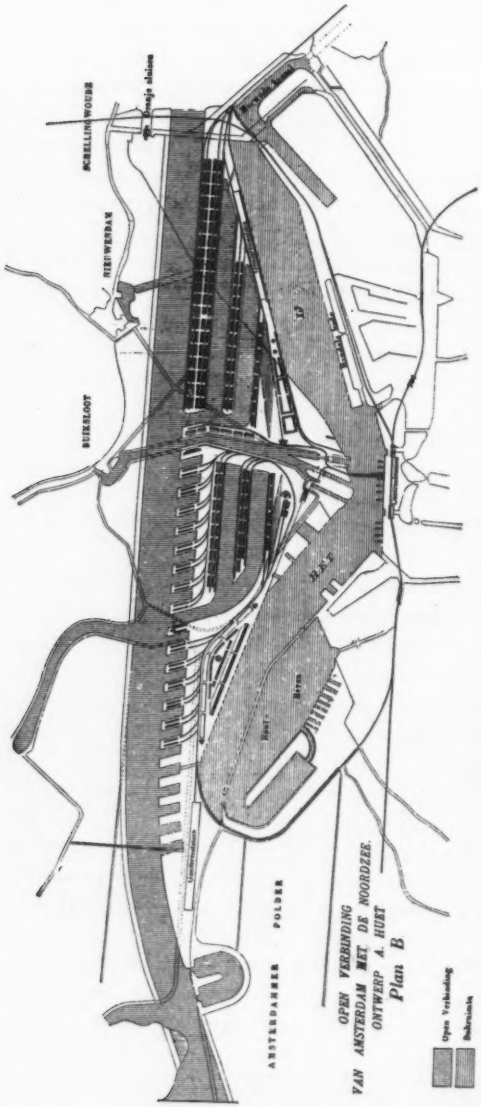
Second.—A large number of projects from 1849–63 for canals with locks at both ends, between Amsterdam and the North Sea.

Third.—A few projects from 1863–74 for an open cutting between the North Sea and the Zuider Zee to provide a free access to Amsterdam.

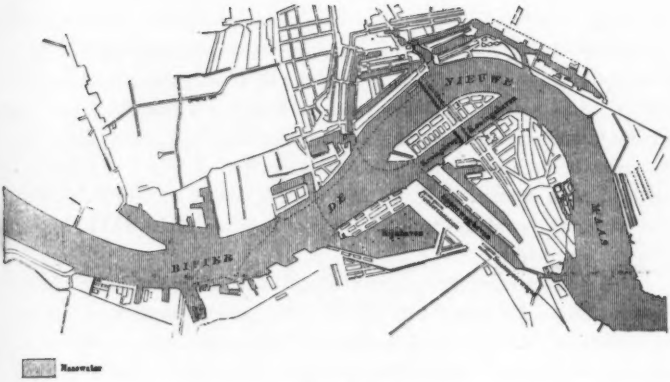
The author of this notice visited Liverpool in 1861 and was profoundly impressed by the enormous extension of trade and shipping he witnessed in that port. He was brought to consider that a perfectly free access to the Atlantic Ocean was a *conditio sine qua non* for the progress of commerce in Amsterdam. In 1862 he obtained a vote of the Congress of the "Netherland Society of Industry," that the possibility of an open sea canal for Amsterdam ought to be seriously examined. A sketch design was given by him in 1863. In the meantime a concession had been given for a canal with sluices, but the works progressing slowly in 1867 and the opening of the Suez Canal which had no sluices, being at hand, the author obtained from the above-named society the appointment of a commission to examine if an open sea canal was possible and desirable.

The canal with locks was finished, as stated above, in 1876, but in the meantime the dimensions of ocean steamers had so much augmented that very soon (in 1886) larger locks proved a necessity, and such are at

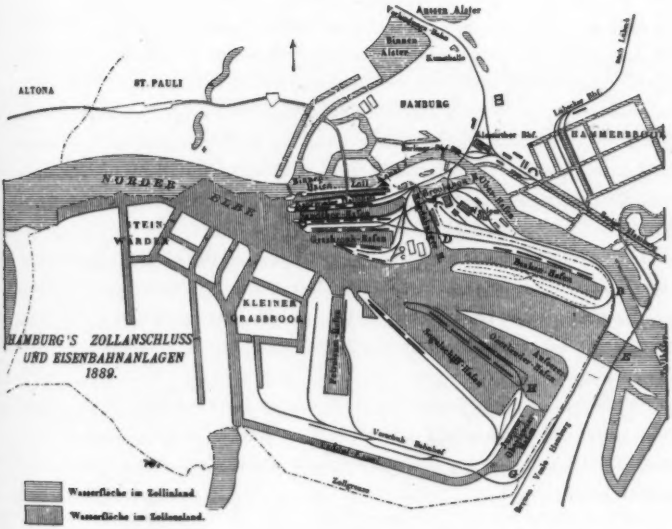
* A complete survey of these projects as far as they were published is given in a paper read before the Institution of Civil Engineers in 1889, and offered by the author to the Congress (No. 2).



AMSTERDAM (ONTWERP).



ROTTERDAM.



HAMBURG.

present in course of construction. The author urged the desirability of an open cutting from Amsterdam to the sea several times in the Institution of Civil Engineers and read a paper in 1884 on this subject.* The debates on this subject ended in 1890 by the Institution inviting the author to make a preliminary project of an open sea canal and by giving him the assistance of an Advisory Commission chosen from the members of the Institution. The president and secretary of this commission were Messrs. T. P. R. Tale van Poortolich and C. Lely, who sometime afterwards became Ministers of Interior Affairs and of Public Works respectively.

This preliminary project was established in an assembly of the Institution on February 14th of this year and is now in course of publication. The principal feature of this preliminary project is an open canal between Amsterdam and the North Sea; length, 28 km.; breadth, 300 m., and depth, 10.82 m. on high water-mark.†

In close relation to this open canal are the projected harbor works for Amsterdam, of which illustrations are given herewith. The illustrations give a comparative view of the harbors of Hamburg and Rotterdam and the projected harbor works of Amsterdam. The intention of the project is to have harbor accommodation for the largest steamers afloat, as the tides between the North Sea and the Zuider Zee insure sufficient and constant depth of water.

There can be hardly a doubt that these works, if executed, would provide a safe and profitable terminal for a direct line of first-class steamers between the United States and the Continent of Europe, which would complete advantageously, the new American line from New York to Southampton.

Close relations have always existed between the United States and the United Netherlands who founded New Amsterdam, and the sympathy between the two nations was sufficiently proved by the loan of $35 000 000 subscribed by the Dutch during the War for Independence.

It would certainly prove a great boon for both nations if it might be possible to enable old Amsterdam to harbor a first-class line of steamers running between New York and Amsterdam, bearing the stars and stripes.

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* A copy of this is offered to the Congress (No. 1).

† A copy of this will be offered to the Congress (No. 3) as soon as it is published.

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654.

(Vol. XXX.—November, 1893.)

THE NORTH AND EAST SEA CANAL.

By J. FÜLSCHER, Geheimer Baurath, Member of Imperial Board of Canal Commissioners at Kiel, Germany.

Translated from the German by KENNETH ALLEN, M. Am. Soc. C. E.

Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

PART I.

HISTORY OF ITS INCEPTION, CONSTRUCTION, AND ITS IMPORTANCE IN UTILITARIAN AND MILITARY ASPECTS.

1. *History of the Canal.*—The project of constructing a water-way between the North and the East seas, which would avoid the tedious and dangerous voyage around Skagen, and connect the two seas more closely in a manner particularly advantageous to Germany, has been discussed for more than five centuries. Three of the projects were actually carried out, but a large number never passed beyond the preliminary work, or the first stages of construction. The completed works are, 1st, the Strecknitz Canal, between the Trave and the Elbe, built in the years 1391–98; 2d, the Alster-Trave Canal, built in 1525;

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3d, the Eider Canal between Holtenau (Kiel) and Tönning, built in the years 1777–84.

The first two canals, of which the Alster-Trave Canal was destroyed in the year 1550, should truly be classed with those inland canals which are not adapted to maritime traffic, even under the conditions formerly attending navigation.

The natural course of the Eider from Tönning to Steinrade was made use of in the Eider Canal, to connect the two seas; and from thence a new water-way was made which included the upper Eider as far as Flemhuder Lake, and then, after breaking through the water-shed north of the city of Kiel, reached the creeks of the same name.

On account of its slight depth, its many windings and its six locks, this canal could aid navigation but slightly. It was therefore the earnest wish of merchants and navigators to inaugurate a change.

These projects served military and political ends as well as assisting commerce, especially where they were promoted by the Germans. On this account none of them have succeeded under the Danish kings, who held entire control of the lines of commerce through the Sund and the Belts.

In the year 1864, after the separation of Schleswig-Holstein from Denmark, the Prussian Ober-Baurath Lentze was commissioned by the Prussian Minister of Commerce to make the preliminary examinations for a North and East Sea Canal.

In the project prepared by Lentze, St. Margarethen-Rendsburg-Eckernförde, which, at the request of the Prussian Minister of War, was changed to St. Margarethen-Rendsburg-Kiel, the canal for the first time assumed the shape of a cut at sea-level with but one lock, at the point where it enters the Elbe. On account of the political events of the year 1866, this plan was not carried out.

Finally, in the year 1878, the final period in the preliminary history of the canal began, when a Hamburg merchant and ship-owner, H. Dahlström, published a document (The Conditions of a Schleswig-Holstein Maritime Canal requisite for Revenue. Hamburg, 1878), and later received permission from the Prussian government to make the preliminary investigations for a line between Brunsbüttel-Rendsburg-Kiel.

In May, 1881, Dahlström presented the preliminary plans for a canal from Brunsbüttel, through Wittenberge, Rendsburg, Steinrade and

Knoop to Holtenau at the bay of Kiel, which he had prepared with reference to their technical and economical aspects. The plans prepared by Lentze, which he voluntarily placed at Dahlström's disposal, served as a most essential foundation. In them the Inspector of Waterways, Boden, who had been engaged to do the technical work, made some important alterations, which were found necessary by later experience and research.

It was this revised plan of Lentze which (with many alterations, especially influencing the cost) was used as foundation by the Legislative bodies—the Reichstag and the Prussian Landtag.

The construction of a maritime canal, suitable for the German flotilla from the mouth at the Elbe *via* Rendsburg to the Bay of Kiel, at the cost of the German Empire, was approved by law, May 16th, 1886, under the condition that Prussia should contribute 50 000 000 marks in advance towards the 156 000 000 marks, the total cost. This condition was agreed to by Prussia, July 16th, 1886.

On July 17th, 1886, a special commission was appointed, under the jurisdiction of the Department of the Interior, and entitled The Imperial Canal Commission, to carry out the building of the canal, with headquarters at Kiel.

The building of the canal itself was inaugurated by the laying of the corner-stone on June 3d, 1887, by the Emperor of Germany, William I. A period of eight years was allowed to complete it, so that, according to the programme, the North and East Sea Canal should be opened in the year 1895.

2. *The Line of the Canal* (see the accompanying map).—The North and East Sea Canal runs from the mouth of the Elbe, *via* Rendsburg, to the bay of Kiel, and its entire length is 98.65 km. (61.31 English miles). Starting on the west at Brunsbüttel, the canal at a distance of 20 km. (12.43 English miles) passes through the territory of the Elbe Marsh, which at many places is below the water-level of the proposed canal, and through the lowlands of the Burg-Kuden Lake, arrives then by a slight rise to the water-shed between the Elbe and the Eider at Grünenthal, at an elevation in round numbers of 24 m. (78.72 English ft.), and reaches the lowlands of the Eider at 40 km. by following the valley of the Gieselau.

Traversing the valley of this river where subject to inundation, the included moors, and the Meckel Lake, the canal approaches the Eider

for a short distance at Schülp, at 55 km., but does not reach the actual river-bed. A dike is built above high water-mark, between the Eider and the canal, to protect the latter from floods.

The valley of the lower Eider is left again at Westerrönfeld, 59 km.

The canal passes around the city of Rendsburg on the south side, reaches the upper Eider Lake at 65 km., and follows it up to 71 km. From here it passes into the territory of the old Eider Canal, whose course was used as much as possible, although with important straightenings and shortenings. It ends at Holtenau, in the harbor of Kiel.

In the entire length of the canal of 98.65 km. (61.31 English miles) there occurs a fall on—

Straight reaches				62.15 km.	(38.62 miles)	=	63.0%
Curved	"	6 000 m. (19 680 ft.),	radius	4.82 "	(3.00 ")	=	4.9%
"	"	5 000 " (16 400 ")	"	5.52 "	(3.43 ")	=	5.6%
"	"	3 000 " (9 840 ")	"	13.23 "	(8.22 ")	=	13.4%
"	"	2 500 " (8 200 ")	"	3.77 "	(2.34 ")	=	3.8%
"	"	2 000 " (6 560 ")	"	0.98 "	(0.61 ")	=	1.0%
"	"	1 700 " (5 576 ")	"	1.99 "	(1.24 ")	=	2.0%
"	"	1 500 " (4 920 ")	"	2.99 "	(1.86 ")	=	3.0%
"	"	1 000 " (3 280 ")	"	3.20 "	(1.99 ")	=	3.3%
				98.65 km.	(61.31 miles)	=	100.0%

3. *The Profile of the Canal* (see the accompanying map).—The canal is shown here in a section. In order to cut it off from the variable water-levels of the Elbe and the East Sea, locks are built at both ends. The mean water-level in the canal is about the same as the mean water-level in the harbor of Kiel, = —0.23 (0.75 ft.).

In the Elbe, at the western terminus of the canal, where the stage of the water is affected by the regular ebb and flood, the mean high-water level lies at + 1.29 (4.23 ft.), the mean low-water level at — 1.50 (4.92 ft.).

The lock in the Elbe at Brunsbüttel will generally stand open during the ebb from the time when the two water-levels are equalized until the beginning of the flood. Vessels can go freely in and out with every tide for from three to four hours.

The lock at the East Sea will, on the other hand, generally stand open, in consequence of the fact that the variations in the water-level in Kiel harbor are usually slight, and will only be shut when the water-level outside rises higher than 0.5 m. (1.64 ft.) above mean water, or falls an equal amount below mean water. Both conditions may be looked for together in about 25 days of the year.

The canal has a depth of 9 m. (29.52 ft.) below mean water. The bed is horizontal from the eastern terminus at Holtenau to Rendsburg, 60 km. From here to the western terminus at Brunsbüttel the bed has an increasing fall of from 1 : 200 000 to 1 : 25 000, according to the fall of the surface which is formed at the ebb when the gates of the lock at Brunsbüttel are open.

Dikes are built up on both banks where the canal traverses lowlands which lie partly below the surface of the canal.

4. *The Cross-Section* (see the accompanying map).—The bed of the canal in the straight reaches and the curves of over 2 500 m. (8 200 ft.) radius has a width at the bottom of 22 m. (72.16 ft.), and up to 3 m. (9.84 ft.) above the bed a 3 to 1, and, to 4 m. (13.12 ft.) height, a 2 to 1 slope. The upper portions of the profile are built differently for the reaches in the lowlands from those in the higher lands. In the latter reaches, a berm at a height of 7 m. (22.96 ft.) above the bed, that is, about 2 m. (6.56 ft.) below the mean water-level, connects with a $1\frac{1}{2}$ to 1 slope protected by stone, which reaches to 1 m. (3.28 ft.) above the usual water-level. At this height lies a second berm 2.5 m. (8.2 ft.) wide which joins the excavated slope of $1\frac{1}{2}$ to 1.

In the lowlands the lower berm is widened on both sides, in order that the cross-section may be widened later without disturbing the dikes.

The dikes, which are to be built on either side, are given slopes of 2 to 1 where the underlying ground has sufficient firmness—natural or artificially increased by laying sand; but where long stretches have a soft foundation, in order to distribute the pressure as much as possible, they are given an inner slope of 6 to 1.

The cross-section of the canal has, at the lowest stage of water, 6.17 m. (20.24 ft.) depth below the surface, an available width of 36 m. (118.08 ft.), and offers a passage to the largest steamers employed in the East Sea traffic, which, with a few exceptions, have a draft of not over 6 m. (19.68 ft.), with a berm of 12 m. (39.36 ft.).

In curves of from 1 000 to 2 500 m. radius (R) a widening of the cross-section is given of $26 - \frac{R}{100}$ m. This widening amounts to, in the curves, of—

1 000 m.	(3 280 ft.)	radius	.....	16 m.	(52.48 ft.)
1 500 "	(4 920 ")	"	.....	11 "	(36.08 ")
2 000 "	(6 560 ")	"	.....	6 "	(19.68 ")
2 500 "	(8 200 ")	"	.....	1 "	(3.28 ")

5. *Facilities for Passing.*—Opportunity for the passage of large ships of war is provided by six places arranged for passing, besides the upper Eider Lake, an average distance apart of 12 km. (7.46 miles). These passing places are given, including the passages, a length of 450 m. (1 476 ft.), and a width at the bottom of 60 m. (196.8 ft.). In the Audorf Lake, east of Rendsburg, there is, moreover, a place where vessels of any size can turn around.

6. *Locks.*—Locks at both terminals are arranged as double locks, each with two openings—one for outgoing and one for incoming vessels. Each opening is given a clear width of 25 m. (82 ft.), and a chamber length of 150 m. (492 ft.).

In order to connect the canal with the lower Eider, a lock will be built near the city of Rendsburg with a width of 12 m. (39.36 ft.), and a length of chamber of 68 m. (223.04 ft.).

7. *Bridges and Ferries.*—Of the four railroads which cross the canal, two, the Itzehoe-Heide and the Neumünster-Rendsburg, cross on drawbridges of unequal spans, with 50 m. (164 ft.) clear span; and two, the West Holstein and the Kiel-Flensburg, cross on high bridges.

Of the latter, the bridge at Grünenthal, which is already finished, has a length between supports of 156.5 m. (513.32 ft.). It is constructed with chords arched in the form of a sickle, on abutment joints, and the track is half the height of the arch.

The high bridges have each a clearance of 42 m. (137.76 ft.) above mean water-level.

The drawbridges, which are moved by hydraulic power, are uniformly constructed with a single track, so that, in the case of the double-track road from Neumünster to Rendsburg, each track is carried across on a special drawbridge.

The highway between Rendsburg and Itzehoe, which is much traveled, crosses the canal also with a drawbridge, constructed similarly to the railway spans.

Beside these, ferries are provided for wagon roads. There are fourteen ferries, making one for each 7 km. (4.35 miles).

8. *Housing and Care of the Workmen.*—The housing and care of the workmen is undertaken by the Government.

The buildings for this purpose consist of camps of barracks for from 100 to 350 men, and of single barracks for 50 men each. Each camp consists of a government building, one or more dormitories and

the necessary out-buildings. All the buildings are framed and of one story. The Government building contains, besides a government office and a store for selling food and clothing, a dining and assembly hall of 180 sq. m. (1 936.8 sq. ft.), a basement with kitchen, pantry, laundry, disinfecting-room, bathroom, physician's room and waiting-room.

The dormitories have rooms which can be heated; containing eight cots each, with 12 cu. m. (423.84 cu. ft.) of air space per capita, and one or more rooms for inspectors.

Workmen who become sick or are injured are treated in the public hospitals at Brunsbüttel and Rendsburg, in the Academical hospitals at Kiel, and in two hospitals at Burg and Hanerau, specially erected by the Canal Commission, and governed by their own officials. Especial arrangements are made for taking the men into the first-named hospitals and into the Academical hospitals.

9. *The Execution of the Work.*—The preliminary work for the canal began in October, 1886. It had progressed so far in the course of a year that they were enabled to acquire the right of way in the fall of 1887, and to make contracts for the earthwork in the first half of the year 1888.

Excavation was begun for a short distance in the vicinity of the western terminus in March, 1888, and was continued in October of the same year. The construction of the locks was begun in the fall of 1890, and of the bridges in the spring of 1891.

The time appointed for the completion of the canal was the year 1895.

The total quantity of earth to be moved consisted in round numbers of 80 000 000 cu. m. (2 825 600 000 cu. ft.). Up to the present time, April 1st, 1893, about 60 000 000 cu. m. (2 119 800 000 cu. ft.) have been moved. The monthly average in the year 1892 was, approximately, 1 400 000 cu. m. (49 450 000 cu. ft.).

For the removal of earth, there were in use in the year 1892:

20 land excavators.
42 floating dredges and excavators.
65 locomotives.
1 790 wagons.
662 carts and wheel-barrows.
11 steam scows.
124 transport scows (sloop rigged).
37 tugboats.

The number of workmen employed averaged, in the winter and fall months of 1892, 5 785; in the spring and summer, 8 270.

10. *The Cost of the Canal.*—The entire cost of the canal was estimated at 156 000 000 marks, or, for each kilometer, 1 580 000 marks (1 mile = 2 544 450 marks = £124 728). Judging by previous and existing conditions, we can safely assume that this will not be exceeded.

11. *The Significance of the Canal.*—The significance of the canal is both military and economic. The military significance consists in having a connection between the North and East seas for the German fleet, independent of foreign countries, so that they may pass unhindered and unseen from the East Sea to the North Sea and *vice versa.*

The economic significance of the canal consists, firstly, in shortening the distance between the two seas, as compared with the present route; and, secondly, in avoiding the dangerous voyage around Skagen, thereby preventing the numerous losses of valuable merchandise, vessels and lives which occur every year in these waters.

The shortening of the route depends, naturally, upon the situation of the various harbors.

As a point of departure for an estimate of the shortening of distance between the harbors of the North and East seas, we take a point between the Peninsula of Wittow, which belongs to Rügen, and Torp, on the southern coast of Sweden, in latitude 55° north, longitude 13° east, from Greenwich, from which the routes of navigation from the East Sea follow a common line through the Sund, around Skagen and through the Skagerrak to the North Sea, and from the Skagerrak radiate towards the different harbors. The shortening of the route between the harbor cities for traffic between the North Sea harbors and the East Sea harbors lying east of a line from Wittow to Torp can be seen by the accompanying summary showing the shortening of time and distance. For Leith, on the west coast of Scotland, this is 83.8 nautical miles, and for Hamburg, 424.8 nautical miles.

If we consider the rate of speed of steamers in the open sea to be $8\frac{1}{4}$ nautical miles, and in the canal to be 10 km. or $5\frac{3}{4}$ nautical miles, per hour; and, moreover, if we allow for the unavoidable stops in going through the locks and bridges, in passing each other, etc., three hours for each trip through the canal, we have the gain of time by use of the canal indicated in the above-mentioned summary.

This gain is much greater for sailing vessels, and, with adverse

winds, may amount to weeks. On an average, it would be about three days. In addition to this gain in time, which corresponds to a gain in freightage, as well as in interest due to the quicker delivery of goods, there is a further economy in using the canal in place of going around Skagen; first, in avoiding the cost of pilotage in the Sund; secondly, in a lessening of insurance for vessels and goods when the voyage is made by way of the more safe canal; and, thirdly, in a saving of the money that would be required to run into a harbor in the Skagerrak and Kattegat, especially in winter.

As an offset to this saving, we have the tariff for the use of the canal, which is so adjusted that there results a gain for each vessel using the canal. In addition, there is the advantage accruing to navigation by the lessened danger consequent on the use of the canal as compared with the voyage around Skagen.

According to authoritative inquiries made up to the year 1866, 200 vessels were yearly wrecked in sailing around Skagen, whose value, aside from the great loss of life, is estimated, after deducting the value of the goods taken on commission, at 14 000 000 marks. Allowing for a decrease in loss on account of the increased use of steamers, there yet remains an annual loss estimated at 8 000 000 marks. The greater part of this loss is avoided by using the North and East Sea Canal, and it is an advantage to those nations which participate in the traffic of the East Sea.

12. *The Prospective Traffic of the Canal and its Capacity.*—The traffic through the Sund, the two Belts and the Eider Canal, serves as a basis upon which to estimate the probable traffic on the North and East Sea Canal.

According to the statistics of the five years 1877-81, the marine traffic of the German, Russian, Finnish and Swedish harbors in the East Sea and harbor of Copenhagen, together with harbors outside the East Sea which would profit by use of the canal, averaged 24 000 steamers and sailing vessels, with an approximate tonnage of 8 300 000. As, however, many vessels which might use the canal to advantage will undoubtedly choose the voyage around Skagen, if they are in no hurry, or meet with favorable winds and weather, the annual traffic on the canal is estimated, in formulating the memorial for the canal presented to the German Reichstag, at 18 000 vessels, with a tonnage of 5 500 000.

Since this time, however, the traffic has materially increased, and there is, moreover, an important change in the relative proportion of sailing vessels and steamers. While, according to Dahlström, in "The Arrangements for the Building and Maintenance of the North and East Sea Canal," the traffic through the Sund in the year 1880 consisted of 28 211 sailing vessels and 9 876 steamers, with a combined tonnage of 12 718 376, in the year 1889 there were much fewer sailing vessels and more steamers. The traffic in this year consisted of 14 114 sailing vessels and 16 448 steamers, with a combined tonnage of 16 022 069.

In these nine years there has been, therefore, an increase in the volume of marine traffic in the Sund of—

$$\frac{16\,022\,069 - 12\,718\,376}{12\,718\,376} \times 100 = 26\%.$$

The number of steamers has increased by—

$$\frac{16\,448 - 9\,876}{9\,876} \times 100 = 67\%.$$

The number of sailing vessels has decreased—

$$\frac{28\,211 - 14\,114}{28\,211} \times 100 = \text{about } 50\%.$$

This averages yearly, therefore, an increase in volume of $\frac{26}{9}$ = about 3%; an increase of steamers of $\frac{67}{9} = 7.4\%$, and a decrease of sailing vessels of $\frac{50}{9} = 4.5$ per cent.

Assuming that this change in the traffic in the Sund is not discontinued in the year 1889, but keeps on in the same ratio, then in the year 1895, the first year of operation of the North and East Sea Canal, the traffic on the Sund will have attained the following proportions:

The total tonnage of vessels will be—

$$12\,718\,376\,(1 + \overline{15 \times 0.03}) = 18\,441\,642 \text{ registered tons,}$$

the number of steamers—

$$9\,876\,(1 + \overline{15 \times 0.074}) = \quad 20\,838 \quad \text{“} \quad \text{“}$$

and the number of sailing vessels—

$$28\,211\,(1 - \overline{15 \times 0.045}) = \quad 9\,169 \quad \text{“} \quad \text{“}$$

In a pamphlet recently published in Kiel by the Geheimer Kommerzienrath Sartori, entitled "Kiel and the North and East Sea

Canal," it is shown that, of the traffic on the Sund in 1887, probably 60% would have passed through the North and East Sea Canal if it had been in existence at that time. Taking this percentage as good for the year 1865, the traffic on the canal during its first year of operation (estimating a full year) will be—

	0.6 × 18 441 642	= approximately	11 600 000	tons
In steamers.....	0.6 × 20 838	= "	12 500	"
And sailing vessels..	0.6 × 9 169	= "	5 500	"

This traffic on the North and East Sea Canal can be easily accommodated with continuous operation, day and night, as the provisions for navigation reach far beyond present necessities, and we cannot err in the assumption that, even with a uniform increase of navigation, the canal will suffice, in its projected capacity, to accommodate the traffic for any conceivable period.

PART II.

Construction of the Canal in the Lowlands of the Burg-Kuden Lake.

General Conditions, Preparatory Work and Designs (with a map, Plate I, Fig. 1, and profile, Plate II, Fig. 2).—From 7.6 to 18 km. the canal crosses an extensive low marsh which, in the last century, served as a collecting ground for the high waters of Holstenau, which were injurious to the Wilstermarsch, although they then had an outlet toward the Elbe; but not until the end of the sixties and beginning of the seventies of this century were they improved by carrying out a systematic scheme of drainage. The profile of the canal here shows a section almost everywhere in a soft and submerged soil for its entire depth. On the top, after the removal of turf to a few decimeters in depth, lies boggy soil (moss peat) in variable thickness; below that, darg (sedge peat), and, lowest of all, clay (clammy marsh soil). The old solid sea-bed, from 9 to 16 km., lies everywhere below the canal-bed, and but little higher at both ends of the lowlands.

In order to arrive at a safe opinion of the supporting power of the top stratum of the soil, experimental excavations were made in several places during the preliminary work. It became evident that, even in the two top strata, slopes of 4 to 1 for a slight depth began to settle without a surcharge, so that, even under a light weight, the clay

became compressed and squeezed out. A surcharge on the banks of the canal was unavoidable, because the highest stage of water in the canal + 20.27 m. (66.49 English feet)* lies some 1.25 m. (4.10 ft.) above the mean elevation of the lowlands, and, therefore, dikes had to be constructed on both sides of the canal, to protect the lowlands.

The most unfavorable of these conditions occurred from 13.2 to 18 km., where the stratum of bog was so thick and so soft that it could scarcely be trodden upon, and where the clay also was less firm than elsewhere. Here it was to be predicted with certainty that, with the excavation for the canal, and especially the construction of the above-mentioned dikes, the material at the sides would always slide. Nothing remained, therefore, but to consolidate the soft material on both sides of the canal, or to press it back by filling in with some firmer material, forming in this way solid bodies acting as dams between which the canal could be excavated without further difficulty. A sandy soil adapted to the construction of these dams was found in abundance in the tract beyond the lowlands, from 18 to 26.2 km. In the excavation of the canal between these sand dams, decided movements and changes were to be expected in the slopes of the dams on the canal side; wherefore, it was necessary to adopt here an excessive width from the first. The width was fixed at 15 m. (49.2 ft.), and the distance between the dams and the axis of the canal was so chosen that the former gave a firm footing for the works on the tops of the banks and the adjoining dikes.

In the section from 7.6 to 13.2 km. the material for the sand dams was more difficult to obtain, the stratum of bog thinner and drier, and the clay was nearly everywhere much firmer. It was proposed to construct this section without sand dams. At a trial excavation at 11 km., slopes of 2 to 1 were found to be stable to the full depth of the canal. The construction of the canal in the natural soil seemed possible as far as it was feasible to build the dikes on either shore, so that their weight on the subsoil induced no lateral pressures on the canal. To attain this end, the plans were arranged so that, first, the banks of the canal and the adjoining berms [2.5 m. (8.2 ft.) in width] should be as high as possible [at + 19.77 m. (64.85 ft.)], and so that the dikes should have a slope of 6 to 1 on the canal side, in order that their crowns

* All elevations which occur in this article refer to a horizontal plane 20 m. (65.6 ft.) below normal zero.

[at + 22 m. (72.16 ft.)] would set back from the edges of the banks of the canal about 16 m. (52.48 ft.). In the Kuden Lake (7.7 to 8.7 km.) where the subsoil was less favorable, the low (embankment) dikes were to be removed from the axis of the canal 70 m. (229.6 ft.).

With the difficulty above mentioned, which arose from the condition of the soil in the lowlands of the Burg-Kuden Lake, the location of the line to be selected required very careful preliminary investigations. Numerous borings were made, extending over the entire area of the lowlands. These proved that the character of the ground on the contemplated line was more favorable than elsewhere, especially on the western border of the lowlands close by the Geest slope, where the line of the so-called Dahlström project, worked up in the year 1880 by the Regierungs-Baumeister Boden, cut across the lowland district. It is true that the soft strata are there not so thick as at a greater distance from the Geest slope, and that the canal bed would therefore cut into the sandy subsoil. But the latter consists of quicksand. In conducting the borings masses of it were mined out by the water flowing over the edges of the bore holes, and it would be a hazardous undertaking to excavate the lower portion of the canal in this material. The necessary dams to be erected on the adopted line will, it is true, be quite costly; but the cost of these can be estimated, and the result is certain. The necessary cost of excavating the bed of the canal in the quicksand could not be predicted, and no assurance could be given that the depth called for in the plans could be reached in this soil by the customary means—dry excavation or dredging under water.

Economic considerations led to a decision in favor of the line adopted. As the plan shows, this line lies in the immediate neighborhood of the district boundary which is, at the same time, the township boundary. It was therefore advisable to buy up the lands lying between the canal and the district boundary, which are cut off by the canal from the township to which they belong, and which are thus inaccessible to their former owners, for spoil banks for which purpose they are well adapted by their position. This also did away with the necessity of arranging for their subsequent economical management, of constructing new roads across the canal, ferries and drainage improvements. Any line lying farther west would have made necessary to continue the profitable utilization of the land so cut off, the estab-

lishment of two ferries, one for Buchholz, and one for Kuden, as well as the construction of parallel roads on the southeast side of the canal, and, in spite of this, the profitable use of the tract so cut off would have been extremely difficult for the former owners. Besides the cost of ferries and roads, and for various new drainage improvements, which would have become necessary in consequence of the division, heavy damages would have been incurred for increasing the difficulty of farming. By the use of the projected line, all these expenses are avoided.

The Execution of the Work in the Section from 7.6 *to* 13.2 *Km.* (see Plates II and III, Figs. 3 to 8).—The work in the section 7.6 to 13.2 km. began by depositing the clay obtained by dry excavation, between 5.8 and 6.6 km., for the formation of dikes as far as 7.6 km. and beyond. But the nearer this construction of dikes approached the Kuden Lake, the deeper they settled into the ground, producing a bulging to the right and left, so that with further excavation slides were to be expected. As, moreover, there was not sufficient material suitable for dikes, the conclusion was forced upon them that it would be necessary to abandon the idea of completing the work without an artificial strengthening of the banks by sand dams. Farther along, in the section from 10 to 12 km., where the upper strata of the soil were removed by dry excavations from the trench and placed to one side, similar experiences were undergone. Only at a few points was the upper stratum firm enough to support the dike without the lateral pressure becoming evident (see the cross-section at 11 km., Fig. 7). Elsewhere, even a slight pressure universally produced motion. It was suggested to remove the bulging slopes of bog for a width of about 3 m. (9.84 ft.) and in their place to substitute a protection of clay of equal amount, which should extend down to the contiguous stratum of clay beneath the submerged embankment. But this was given up because it was feared that the water contained in the soil adjacent, being prevented from escaping by the clay protection, would induce sliding under the pressure of the dike. It was therefore decided to construct such a protection of sand. For this purpose the track, which had already been laid for the filling in of the sand dams from 13.2 to 18 km. with material from the cut in the canal reaching to 26.2 km., had to be prolonged for the whole length of the section in question. This was a difficult piece of work

on account of the slight supporting power of the top stratum. When they began to fill in with sand, the clay was found to be so soft, with the exception of a short stretch, that the sand was soon pressed out of position (see cross-sections, Figs. 6 and 8), and so, in place of the proposed construction of the slopes, real sand dams were built similar in form to those upon the section 13.2 to 18 km., where the construction of such dams had been foreseen from the first. After this experience the attempt to make the slope protections of a given uniform width was abandoned, and the plan of building regular sand dams was adopted.

In the section from 10 to 12 km. the canal was excavated to + 15 m. (49.2 feet), and some of the material for the dikes banked up, before they began the filling in of the sand dams. From 12 to 13 km. and from 10 km. to the Kuden Lake the dams were made in the same way as in the firmer section, 13 to 18 km., where the tracks for extending the work could be relaid upon the top stratum. In relation to the various particulars of the construction the reader is referred to the description (see p. 436, *et seq.*).

For the damming of the Kuden Lake (see Plate II, Fig. 3) a float was employed, by which the work was carried on in the following manner. The material was brought in cars containing 3 cu. m. (105.96 cu. ft.) as far as the tracks allowed, and dumped; then, when the train had gone away, it was taken up in buckets with a capacity of 0.5 cu. m. (17.66 cu. ft.) and dumped on the platform between the end of the dam and the float, to both right and left. Eight or ten buckets were employed for this, which, after being emptied, were taken to the siding between the track and the windlass. After all the cars were emptied, they were taken back to the place for loading sand, and the operation was repeated in the manner described. As soon as the extension of the sand dam had a sufficient power of support, the float with the windlass was drawn forward, the track for the large cars extended, and then the operation was repeated.

We have still to mention a peculiar task with which the commissioners had to occupy themselves before they could begin constructing the dams. The cultivation of the plains, which are drained by removing the peat to + 18.00 m. (59.4 ft.) and then pumping, is accomplished by excavating the fertile calciferous clay (which is usually found in large deposits under the bog and sedge-peat strata) to a depth of

10.5 m. (34.44 ft.) and spread in thin layers over the meadows. For this purpose, peculiar contrivances are used for excavating, called *ketscher*, by the use of which ditches of corresponding depth are cut, about 40 cm. (1.31 ft.) wide, with vertical walls, are formed. These cross the land to be diked here and there, and had to be barricaded where not sufficiently protected by deposits, or where compression by the canal dikes was definitely not to be expected, in order to prevent the water in the canal above from breaking through into the lowlands. The ditch in the diked land to be built over was filled up with sand according to its depth for a length of from 6 m. (19.68 ft.) to 8 m. (26.24 ft.), and through this fill, at right angles to the length of the ditch, sheet piling was placed 2 to 3 m. across and 8 to 10 cm. thick, which should reach to at least 1 m. below the bed of the ditch. In Plate II, Fig. 4, the process is represented. Investigations and observations of the ditches so crossed have shown that the desired result has been attained.

Sand Dams on the Section from 13.2 *to* 18.0 *Km.* (see Plate V, Figs. 11 and 12).—The process of construction differed according as the sand dam was to be built on a firm bed or on one which was soft.

With a firm bed (Fig. 11) the experiment of removing the tough morass cover under the sand dam proved judicious, as, by allowing it to remain and simply loosening it laterally (by narrow trenches), there would usually occur in the operation of filling in the sand a separation of this "mattress" into two parts, preventing the lateral spreading of the sand by assuming an oblique or vertical position. Furthermore, it seemed advisable, in order to effect the most favorable formation of the mass of sand, to give the sand on the edge nearest the canal as deep a bearing as possible. The course pursued in filling in the sand developed as follows in the case of a firm cover of bog.

(*a*) Excavation on the site of the proposed sand dam to a depth of 0.5–1.0 m. (1.64–3.28 ft.), and a width of 12–15 m. (39.36–49.20 ft.).

(*b*) Filling in this trench with sand brought from the completed dam in the rear by means of hand dump cars.

(*c*) Extension of the main track for transporting material [of 0.90 m. (2.95 ft.) gauge] on the edge of the fill next the canal.

(*d*) Dumping the cars loaded with earth [capacity, 3 cu. m. (105.96 cu. ft.)] near this edge until the resulting banks of sand did not sink appreciably.

(*c*) Widening this narrow body of sand on the outer side until the desired width was attained.

For about 800 m. (2 624 ft.) in length of the canal between 16 and 17 km., where the surface of the bog was quite soft and inundated, the preceding excavation was not necessary; but, on the other hand, the preliminary use of rammed piles became necessary. The method of procedure was as follows (see Fig. 12).

(*a*) Driving in light pile-piers in the center of the sand dam penetrating the firm subsoil, and carrying on them a track of 0.6 m. (1.97 ft.) and 0.9 m. (2.95 ft.) gauge (with a common rail).

(*b*) Piling up sand around the piles at night with hand dump cars [of 0.6 m. (1.97 ft.) gauge] from the finished section of the dam behind, in order to enclose the heads of the piles and prevent the pressing in of the bog near the end of the sand dam.

(*c*) Carrying forward the true sand dam with cars of 3 cu. m. (109.96 cu. ft.) capacity, and 0.9 m. (2.95 ft.) gauge in such a manner that the cars unloaded at the end of the dam should be pushed forward on the track mentioned in *a*, which extends over the end of the dam. For a short distance from the end of the sand dam the track should be supported by ways on cross-ties, floats of oil barrels, etc., in place of the piles, which are gradually all broken off by the forward motion of the dam.

(*d*) Widening the dam to its whole width.

By this procedure, especially by the pushing forward of the empty cars on the track laid on piles, the rapid unloading of trains (of 10 to 15 cars), and therefore the rapid progress in the construction of the dam was accomplished.

Results of Filling in with Sand (see Plates III and IV, Figs. 7 to 10).—So far as it could be effected by details in the course of the work, it was attempted to give the sand dams equal slopes on both sides, and where the subsoil was of uniform quality this was successful (see cross-sections, Fig. 10). Exceptions occurred where firm layers of clay with sloping surfaces occurred, in the subsoil, or where (by water courses) there were old and solid dikes on the surface, or where at the beginning of the fill the canal had been partly excavated—where the site of the dike was somewhat overloaded. Under these circumstances a widening of the underlying sand took place towards the outside, or towards the inside of the canal, which, with an increase

pressure upon it, was simply widened without being forced deeper in. The desired forms were established by numerous borings (see cross-sections, Figs. 5 to 10).

The ground displaced by the embankment rose on either side forming irregular upheavals, which frequently extended across the entire space between the dams on the two sides (see cross-sections, Plate IV, Figs. 9 and 10), and rose to 3.20 m. (10.50 ft.) above the original surface, when, after a period of rest, they settled again somewhat. The quantity of sand delivered was estimated by the contents of the transport cars, or by the volume of the unheaved mass within the canal (the volume above of the original estimate) by repeated measurements of the cross-section. The quantity of sand used from 8.2 to 13.2 km., was 590 000 cu. m. (20 838 800 cu. ft.), and the volume of the upheavals resulting therefrom in the canal was 250 000 cu. m. (8 830 000 cu. ft.). From 13.2 to 18 km., 1 216 000 cu. m. (42 949 120 cu. ft.) of sand were used, and the upheaved volume was here 223 000 cu. m. (7 876 360 cu. ft.). The less fortunate condition in the lower section probably resulted from the fact that in consequence of the deeper preliminary excavation for the canal, between 10 and 12 km., the mass of sand settled more towards it than to the outer side; that the ground here, being firmer, was less compressed, and that in the upper section a large amount of sand was used whose excess resulted in no further bulging.

Excavation of the Canal.—According to the specifications, the contractors could only begin excavating between the sand dams after six months of settlement; in reality this time had to be shortened in some sections, as otherwise the excavators would have lain idle. The canal was first excavated in dry material to the banquettes under water with carts, and the material taken out was used partly in building dikes, and partly laid on depositing beds, being used there in the formation of enclosing dikes. In the section from 7.0 to 12.4 km., one large and one small bucket-chain excavator and one pump excavator were used. The latter discharged the mud on the depositing beds through a pipe, while the material raised by the bucket-chain excavator was carried to its destination by two elevators. In the section from 14.8 to 18.0 km., a bucket-chain excavator with a Vering floating apparatus, and temporarily a second bucket-chain excavator with an elevator, have been in use since October, 1891. The section from 12.4 to 14.8 km. as yet remains dry.

Although the bed of the canal has been reached in many places, there have been no large slides in the sand dams, except in one instance—at 14.8 km.—where the borings for the sand dams indicated such a result as probable.

Location of the Dikes.—In the section 13.2 to 18.0 km. but little has been done to the dikes; where the depositing beds are by the canal, as is here generally the case, the masses of earth moved by the apparatus of the excavators are deposited immediately behind the sand dams.

In the lower section 7.6 to 13.2 km., where the flat-dike profile is retained in spite of the sand dams, the dikes are raised to + 20.0 m. (65.60 ft.) with bog soil, to level up the inequalities of the dike lands; marsh land, where over + 20.0 m. (65.60 ft.), is generally leveled off to this height. In this way a level base is formed for the dikes which are to be built of clay, and arranged in such a way that the ground is uniformly loaded. Further building up is performed mainly with an elevator, with a trough having a steep inclination (see Plate V, Fig. 13), which receives the necessary material from a bucket-chain excavator. The steep inclination of the trough renders it possible to handle the material without the assistance of water, in which way the softening of the dike land is avoided. By the constant moving to and fro of the elevator, a gradual and uniform loading of the dike land is accomplished, and it is hoped that in this way slides and uneven settlements will be avoided as much as possible.

PART III.

The East Sea Locks at Holtenau.

I. *General Considerations.*—The East Sea locks at Holtenau form a portion of the lock and harbor works which are being constructed in the vicinity of Kiel, at the eastern terminus of the North and East Sea Canal. They cut off the canal from the harbor of Kiel, and also from the East Sea. Plate VI (Fig. 1) gives a view of the entire harbor works, yet incomplete, the most important features of which are the double locks.

II. *Description of the East Sea Locks.—a. Object of the East Sea Locks.*—The North and East Sea Canal forms, as it were, a strait, whose ordinary surface corresponds to the mean level of the East Sea. As the mean water of the East Sea is at about the same elevation as the mean water of the Elbe at Brunsbüttel, the locks at both ends might be dis-

pensed with were it not that both the East Sea and the Elbe are subject to considerable variations in their water-surface.

In the East Sea, it is true, there are no great changes in the tides, but the maximum and minimum water-levels differ from the mean level by from 3.17 to 2.09 m. (10.40 to 6.85 ft.). It is proposed to leave the gates of the East Sea locks open, with the frequent slight changes of level, so that vessels may pass through without delay. Only when the East Sea rises 0.50 m. (1.64 ft.) above mean water, or falls 0.50 m. (1.64 ft.) below it, will the gates be closed, and then all vessels must be regularly "locked" through. In establishing the depth of the canal the occasional opening of the locks was taken into consideration, the depth being made greater by 0.50 m. (1.64 ft.), *i. e.*, it was increased from the 8.50 m. (27.88 ft.), necessary for the largest war vessels, to 9 m. (29.52 ft.) at mean water-level of the canal (East Sea).

b. General Arrangement and Principal Dimensions.—As one lock would not suffice when there is much traffic, two locks are built beside each other. Another advantage is that the canal need not be closed when one lock is being repaired, or is otherwise rendered useless.

The locks had to be provided with double pairs of gates, on the outside as well as inside, as the outside water-surface of the East Sea is sometimes higher and sometimes lower than that in the canal. The gates in the interior of the lock are not used for locking. They are only used when open passage is closed at mean water in the East Sea. It has been ascertained by calculation that every time the water outside rises or falls rapidly, considerable currents are formed in the canal and locks which, under some circumstances, attain a velocity of 1 m. per second. The calculations show, moreover, that with these comparatively swift currents it would be very difficult and dangerous to close the heavy gates. In order to shut off the current with safety, special "shutting" gates were made, the details of which are described further on. As soon as the shutting gates have accomplished their purpose, *i. e.*, have brought the water in the locks to rest, the regular gates are closed and the shutting gates returned to their recesses, where they remain until it is again necessary to close the locks against the current.

In order to drain the locks dry, rabbets are placed at both ends, into which pontoon gates can be inserted.

The available length of the locks is 150 m. (492 ft.), the length of

the structure being about 217 m. (711.76 ft.), the width between gate piers and in the chambers 25 m. (82 ft.), and the depth of the mitre-sill below mean water 9.57 m. (31.39 ft.). In order to protect the canal and the lower land from the high water, the heads of the locks are built 4 m. (13.12 ft.) above mean water in the East Sea.

Approaches 200 m. (656 ft.) and 100 m. (328 ft.), respectively, adjoin the locks in the outer and inner harbors.

c. Description in Detail.—1. *Ground to be Built Upon.*—The strata uncovered during constructions showed deep intersections by cross-veins which are ascribed to a damming up during the two ice periods in prehistoric times in Schleswig-Holstein. In general a stratum of yellow clay 5 m. (16.40 ft.) thick was found under the vegetable mould, below that usually a stratum of sand which, in turn, lay above a thick bed of blue clay or potter's clay, and, breaking through this in places, a layer of coarser sand is found which contains a quantity of water under heavy pressure. At the northeast wing of the locks, at a depth of 13 m. (42.64 ft.) below the surface of the meadow, a boggy material was found overlying an unstable subsoil of blue clay and potter's clay.

2. *Concrete and Masonry.*—The foundation of the locks consists of a a layer of concrete 2.5 to 3.5 m. (8.20 to 11.48 ft.) thick, enclosed by sheet piling. Where possible, as in the lock chambers, the bed of concrete was given the form of an inverted arch (Plate VII, Fig. 4). At the three heads the form was that of a horizontal rectangular girder (Plate VII, Fig. 3), whose under surface was raised at the side walls in order to economize in the length of sheet piling and to give the latter a firm bearing during the time of deepest excavation and of laying concrete.

The concrete on the bed has three conduits (Plate VII, Fig. 5) diagonal to the axis of the lock, which are curved and enclosed with plates of lead on account of its greater imperviousness to water. The object of these conduits is to convey pipes for hydraulic pressure and heat from a central station lying south of the locks to the machine chamber of the three lock walls. They are also to be used for telegraph and telephone wires.

The masonry above shows on the inside the great culverts with which the locks are filled and emptied. The position of the culverts may be seen in the ground plan (Plate VIII, Fig. 6), and in the cross-sections (Plate VII, Figs. 3 and 4) of the mouth, in the longitudinal sec-

tion (Plate VII, Fig. 5). In order to obviate the formation of strong currents and eddies in filling the locks, the water does not enter the lock chamber in an unbroken stream from each culvert, but through 12 smaller apertures whose combined cross-section is greater than that of the culvert (12 : 7.6 sq. m., or 129.12 : 81.78 sq. ft.), which are distributed over the entire length of the chamber.

In the upper part of the lock walls are the extensive machinery chambers whose arrangement may be seen in the ground plan (Plate VIII, Fig. 6), and the cross-sections (Plate VII, Fig. 3), and in the separate plan of the machinery (Plate IX, Figs. 7 and 8). The covering of the machinery chambers could not be effected with freestone.

1. Because the joints occurring between the two latter could, with difficulty, be kept permanently water-tight.

2. Because the roofing would have been very heavy.

3. Because but a limited height was available for it if the deepest machinery chamber were to be built above mean water-level in the canal.

For these reasons a different roofing was required, and after extended experiments the best was found to be a *monier* roof of peculiar cross-section, laid between iron girders, over which a layer of melted asphalt 3 cm. (1.2 ins.) thick is placed.

The upper part of the concrete bed, the design of the mitre-sill, etc., are clearly shown on Plate VII, Figs. 3 and 4, and Plate VIII, Fig. 6.

The wings which were separate from the actual lock walls could, for the most part, be built directly upon the ground, except the north wing, which had to be built on a grillage set on piles, on account of the boggy soil found there.

As to the materials for the walls, the following is noted: The concrete of the lock bed is composed of a mixture of 9 parts of broken stone (granite) and 5 parts of trass mortar. This trass mortar, which is prepared in mills, is composed of 1 part, by volume, of trass, $\frac{2}{3}$ part of fat lime, and 1 part of sand. The mixing of the broken stone and mortar was carried on in the ordinary wooden drums.

The masonry superstructure and the covering of the concrete in the lock and gate chambers, as well as the wings, are built of brick. Granite blocks are used on all projecting parts, or on those which are exposed to injury, as well as where special dimension stones are necessary. With these exceptions the outside walls are covered with clinkers

in rough-cast mortar, which are brought from Sweden and are particularly tough and very regular in form. Rhine basalt lava is used for covering the lock walls, excepting the machinery chambers. In order to save expense large cavities are left in the brick masonry in the interior of the thick walls, which are rammed full of concrete—a mixture of 1 part, by weight, of cement and 8 parts of sand. The common stones used in the backing are prepared in a kiln arranged for the purpose, in which the brick clay excavated in digging the canal is burnt. The mortar used in the superstructure masonry is composed generally of 1 part by weight of cement, ½ part of fat lime, and 4 parts of sand. This mortar is prepared in the same mills which served for the trass mortar. Comparative experiments have shown that the mortar prepared in the mills is very much stronger than that prepared by hand or in a mortar trough, on account of the more intimate mixture of its ingredients.

In the rough-casting and freestone masonry cement-sand mortar was used, mixed in the proportions 1 : 2 and 1 : 1, respectively. In the construction of the locks there was used approximately—

60 000	cu. m.	(2 119 200	cu. ft.)	concrete.
5 500	"	(194 260	")	freestone masonry.
65 000	"	(2 595 800	")	brick masonry.
10 000	"	(353 200	")	rammed concrete.

The brick masonry, including the rough casting, consumed 26 000 000 bricks.

3. *The Gates.*—The lock gates are arranged as mitre gates. A marked difference exists in the manner of constructing the lock gates and the shutting gates, on account of their different uses. The former are divided into those which shut out the flood in the East Sea and those which hold the water at canal level during the ebb. The head gates are designed as ordinary gates, as they have been transformed from wood to iron methods of construction. The low tail gates, on the contrary, were planned as so-called "fish-pond gates," by which a single strong bolt above holds the gate, vertical posts transferring the hydraulic pressure below directly to the stone sills, and above, to the aforesaid bolt. All the gates together with double-lead water-tight sheathing form caissons.

The shutting gates are so arranged that they can be closed by rush-

ing water without danger. For this purpose they have a large aperture which can be closed by sluice gates, which are left open during the closing, in order to leave a large part of the cross-section of the lock free for the passage of water. Only when the gates are entirely shut are the apertures slowly closed. Until then the sluice gates hang by pulley chains in front of the box (which forms the lower part of a gate wing). That they may be more easily operated, they are supplied with cast-iron pulleys, by which they are moved on guide rails. The gates are made chiefly of cast iron; the sluices of the shutting gates, of oak.

4. *Pontoon Gates, Sluice Gates of the Feeding Culverts enclosed in the Masonry Capstans, Futtock Heads, Stairs and Fenders.*

At both ends of the locks there are rabbets encased in freestone, in which the pontoons may be set, making the locks water-tight from the inner and outer harbors. The pontoons are made in the usual manner, as a kind of vessel of cast iron. The water ballast is provided for in such a way that the pontoons rise and fall automatically.

The feeders of the locks are closed by wooden rolling sluice gates, which are similar to those of the shutting gates.

The locks are provided with a number of capstans, by which vessels may be drawn in and out, as well as other assistance rendered. Futtock heads and stairs also belong to the equipment, the latter leading from the top of the lock walls to the water.

Floating fenders of wood made of several strong pieces of timber bound together prevent vessels from bumping against the masonry walls. This precaution is taken particularly on account of the passage of large war vessels. If it should be necessary to use the full width of the locks, the fenders can be readily disengaged from their chains at any time and removed.

5. *Mechanical Devices Used in the Locks.*—All the movements necessary in operating the locks, with their gates, sluice gates or capstans, are performed by hydraulic power, but the design is such that, if necessary, they may be done by hand.

The hydraulic pressure is brought from a central station located south of the locks to the hydraulic motors, which are placed in the machinery chambers of each lock wall. Three-cylinder rotating machines are used entirely as motors. As a rule, the arrangement is such that several hydraulic motors work on a common axle, in which way,

by a shifting of the wheels, which may be thrown out of gear when necessary, the gates can be opened and shut, the sluice gates and shutting gates can be raised and lowered, or, finally, the capstans driven. By an extremely simple device in the hydraulic-pressure pipes, corresponding parts on both sides of the same lock move simultaneously and with equal rapidity. The same arrangement makes it possible to produce all the movements from the middle wall of the locks. A gang of men on the side walls will be necessary only for supervision and for services occurring seldom and at stated times. Plate IX (Figs. 7 and 8) illustrates exactly the arrangement of the whole and of the separate hydraulic motors.

It remains to be said that the corresponding shutting gates of both locks perform their motions simultaneously ; that all gates are turned by transferring the motive power by strong racks and pinions ; that the capstans at the ends of the locks have each an especial motor, and that the pressure of the water is 50 atmospheres. All the machinery chambers and passage-ways can be heated by steam by means of steam pipes connected with the boiler in the central power station.

6. *The Approaches.*—The timber approaches provided in the inner and outer harbors in connection with the locks serve as guides for ingoing and outgoing vessels. They consist of timber floats which rest against huge clusters of piles, which are able to withstand the shocks from moving vessels.

III. *Description of the Execution of the Work.*—1. *Earthwork.*—On January 5th, 1889, the construction of the East Sea Locks was begun by excavating to a depth of + 13.77, *i. e.*, to 6 m. (19.68 ft.) below mean water of the East Sea. This excavation was surrounded by embankments, which insured protection from the storm floods of the East Sea. The greater part of this work was completed in the course of the same year.

All elevations in this paper refer to a datum plane lying 20 m. (65.60 ft.) below normal zero, or 19.77 m. (64.85 ft.) below mean water of the East Sea.

2. *Control of the Water.*—At the same time experiments were made as to the most successful method of controlling the water for the subsequent work of excavation and laying the foundations. The borings made indicated that a stratum of sand, lying at about ± 0, contained pure water under such a high pressure that it rose in the tubing to

+ 23.77 m. (77.97 ft.) and spouted from the deeper borings as from artesian wells. The ground-water which came up was, as expected, fresh. It is evidently under the pressure of higher and, perhaps, far-distant sources, and flows, as a subterranean stream, to those deep-lying portions of the East Sea where the sand stratum containing the water crops out in the sea. Careful observations of the behavior of the ground-water which were made during construction in the excavations as well as in their surroundings, confirm this hypothesis. With the high pressure of the water in the sand stratum it was feared that, after the excavations in the earth for the concrete bed of the locks were completed, the stratum of clay left between the latter and the water-bearing sand could not withstand the pressure of water from below. It was anticipated that under this pressure strong springs and possibly even larger outflows would occur, and that the pumping of the water would result in a constantly increased loosening of the soil. In order to avoid these evil consequences it was necessary, either to allow the water to rise in the trenches to a considerable height and to lay the concrete under water, or to drain the lower sand stratum in the most judicious manner and thus to lessen the pressure there. The latter method was chosen. A timber shaft was sunk to the lower stratum of sand and furnished with a powerful pump, and in this way it was ascertained that the stratum could be drained and the water pressure diminished by pumping. Three masonry wells, having outer diameters of 5.04 m. (16.53 ft.) and inner diameters of 3.50 m. (11.48 ft.), were sunk to the bottom of the excavation [temporarily at + 13.77 m. (45.17 ft.)], but outside of the sheet piling of the locks. This work was begun on April 12th, 1890, and finished on November 20th of the same year. The lower edges of the wells are at elevations of — 2.13 m. (6.99 ft.), — 0.41 m. (1.34 ft.) and — 0.47 m. (1.54 ft.), respectively.

A fourth well which was originally planned for was afterwards found unnecessary.

The wells were excavated and sunk by the use of compressed air, and filled at the base with coarse sand, gravel and stones, as in a filter. Plate VII, Fig. 4, shows a section of one of the wells which, when the locks are completed, is to be built up to the top of the lock platform and arched over, to be used again in case it is found necessary to drain the locks to lessen the pressure on the lower part of the masonry foundation.

The contracts for the foundations and masonry were awarded in the fall of 1890, and the work begun in January, 1891. The wells were first provided with rotary pumps, and these set to work to drain the lower sand stratum. The control of the ground-water and the desired diminution of pressure were thus attained in the most satisfactory manner. Iron pipes were laid around the excavation at the depth of the sand stratum to observe the intensity of water pressure, and the water stage was taken at regular intervals. During the first months the water sank rapidly, but afterwards more slowly. On the 1st of April, 1892, *i. e.*, after about 1¼ years of constant pumping, the stage in the pipes, which at first reached the average elevation of + 22.02 m., had sunk about 10.25 m. (33.62 ft.) to + 11.77 m. Three boring tubes, which were afterwards driven under the middle wall, indicated a stage, on an average, of less than + 7 m. (22.96 ft.), so that the head of the ground-water in the inside of the excavation was diminished by more than 15 m. (49.20 ft.). There resulted from drawing off the ground-water an excavation almost completely dry, into which the strata of clay allowed no water to pass, and the sand stratum, which was exposed in some places, allowed but a few springs with slight pressure to come in. The water entering by these springs, as well as all water entering the excavation from outside, was conducted to the wells through clay pipes 30 cm. in diameter, laid with open joints in gravel through the entire length of the middle of each wall. Two transverse lines connect these pipes with one another and with the three pump wells, forming a complete network of drains, with minor lateral lines. The cross-sections (Plate VII, Figs. 3 and 4) show the position of the clay pipes.

The three pump wells have cost about 100 000 marks, exclusive of pumps, but this is more than balanced by the greater economy in construction—the lessening of the earthwork and the thickness of the concrete, the substitution of thin partitions (moulds) for the temporary sheet-piling of the middle wall, etc.

3. *Work on Foundations and Laying of Masonry.*—From this point the work was regularly prosecuted without any particular events.

The foundation work was begun on the 19th of March, 1891, by deepening the excavation to + 10.77 m. Next, the concrete and masonry of the lock walls were finished, and, after the latter had entirely settled, the concrete and upper masonry of the lock beds were completed.

After the earthwork was carried down to + 10.77 m., the sheet piling of the side walls was driven. The earth between these rows of sheeting was dug out to the projected depth and the concrete then laid. The earth under the middle wall was removed, and after the moulds provided for enclosing the masses of concrete were torn down, the concrete was laid there also.

Excavation was done partly with a "dry" excavator and partly by hand. The sheet piling was driven mostly with direct-acting drivers; in a few cases with steam pile-drivers. The concrete was laid to its full thickness at once by means of a tipping trough with a light tamping of the surface.

Concrete work on the longitudinal walls was begun July 6th, 1891, and finished November 25th, 1891. In the beginning of September of the same year the concrete first laid had sufficiently hardened to begin the upper masonry.

The winter interrupted all work, which was resumed in March, 1892. The lock walls were nearly completed in the year 1892. It was possible to lay about three-fourths of the concrete of the lock beds during the second half of the year 1892. It is expected that the concrete and masonry will be completed during the year 1893, excepting for a few pieces of supplementary work.

4. *Gates and Mechanical Arrangements.*—The gates which are already begun are expected to be placed in July, 1893. Portions of the machinery were installed in the machinery chambers of the side walls in 1892. The placing of the gates and the installation of the machinery necessary for their operation, as well as for working the sluice gates, the feeder gates and the capstans, are to be finished according to the contract by April 1st, 1894.

5. *The Approaches.*—The completion of the approaches will be prosecuted during the years 1893 to 1895.

6. *Time of Completion.*—It is intended—and without unlooked-for delays it can be accomplished—that the East Sea locks shall be ready for use July 1st, 1894, so that the removal of the coffer-dams can be begun. The opening of the entire canal for commerce will follow in the summer of 1895.

Kuden-
See
Brake

Maafsstab der natürlichen Länge.

Fig. 2. Geologisches Längenprofil.
(Geological section of the canal-line.)
Km 6,80 - Km 18,00

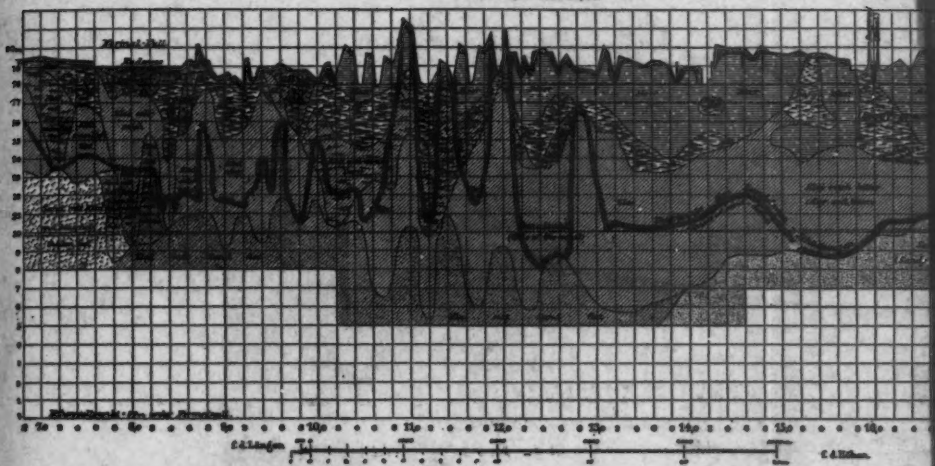
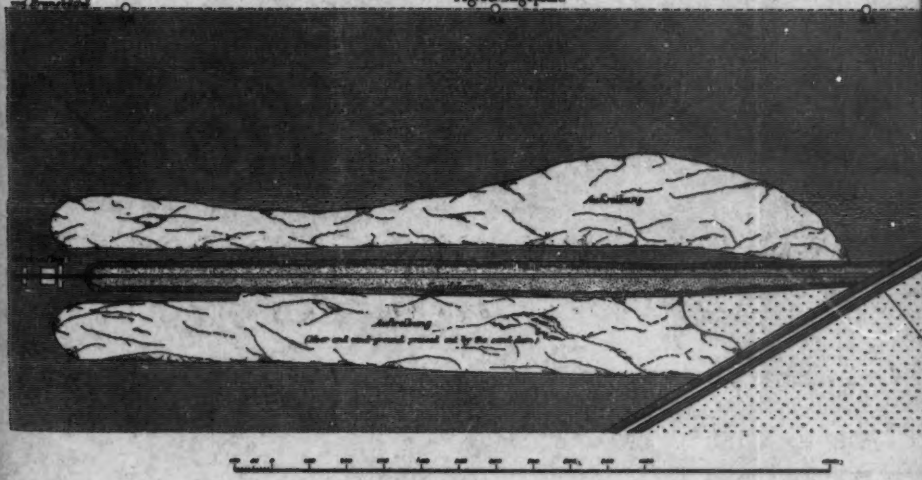
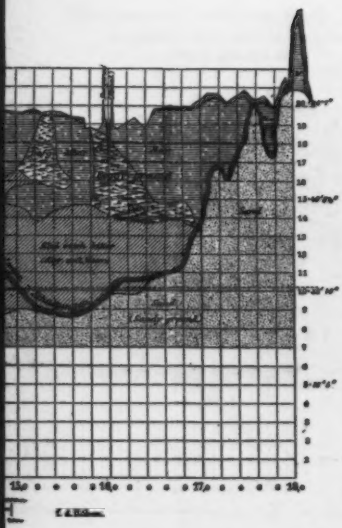


Fig. 3a-c. Schüttung der Sanddämme im Kudensee.
(Casting up of sand-dams in the Kudensee.)
Fig. 3a. Lageplan.





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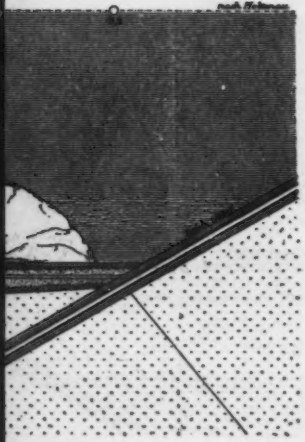


Fig. 4a-d. Verbauung der Ketschergräb
(Filling up the narrow ditches. Depth 20-33')

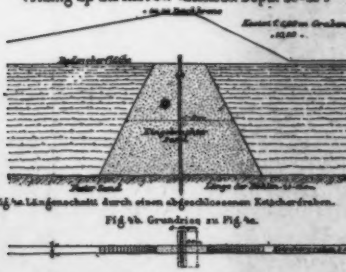
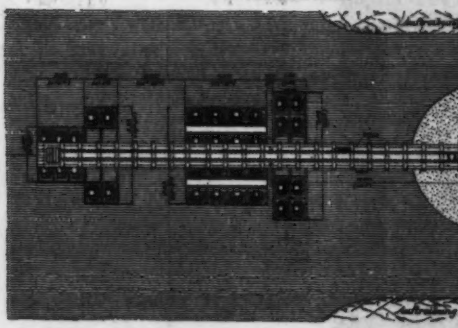


Fig. 4a. Längsschnitt durch einen abgeschlossenen Ketschergraben.
Fig. 4b. Grundriss zu Fig. 4a.

Fig. 3b. Längsschnitt durch die Schwimmflossvorricht
(Longitudinal section of the float.)

Fig. 3c. Aufsicht auf die Schwimmflossvorrichtun
(Plan of the float.)



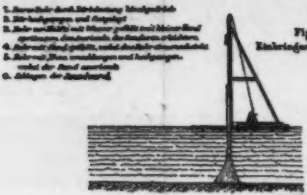
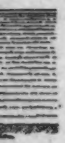


Fig. 4c. Einbringen der Senken.

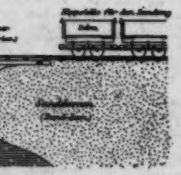
1:400.

gräben

-33')



orrichtung.



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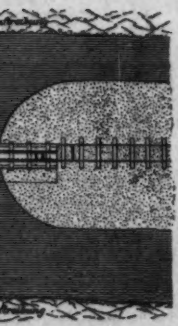


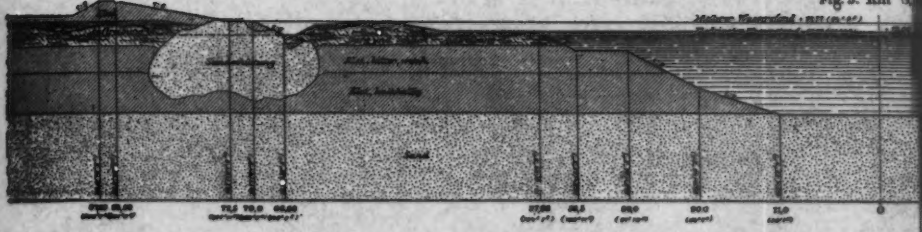
Fig 44.
Unterer Theil
des Senkrohres.

Grundriss

Fig. 5 - 8. Quer

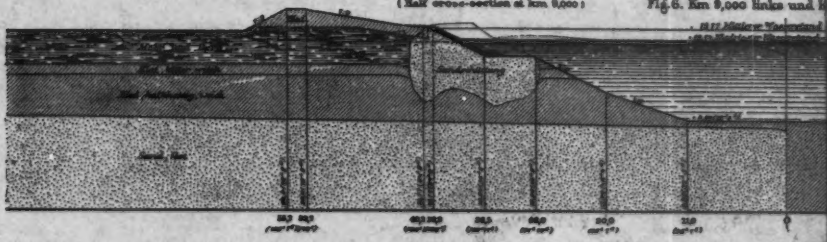
(Cross - secti

Fig. 5. Km 3



(Half cross-section at km 9,000)

Fig. 6. Km 9,000 links und



(Half cross-section at km 10,100)

Fig. 7. Km 10,400 links und

Fig. 8. Km 12,

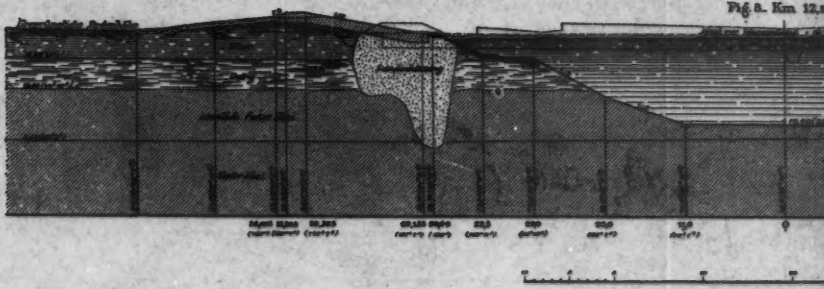
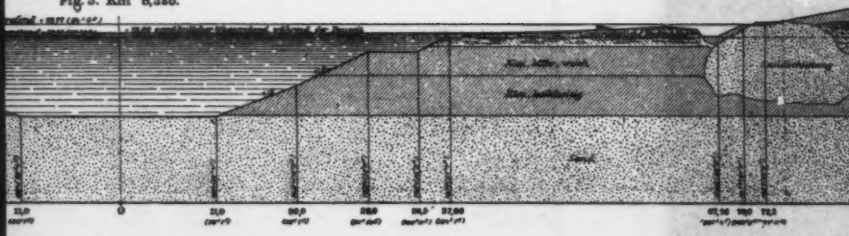


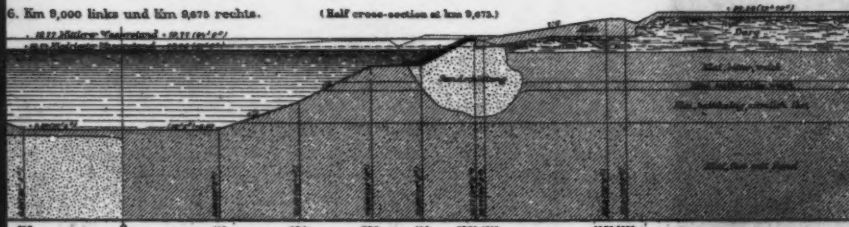
Fig. 5-8. Querprofile.

(Cross - sections.)

Fig. 5. Km 8,350.

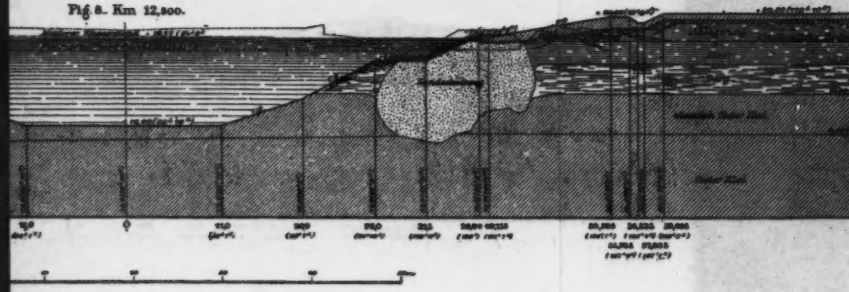


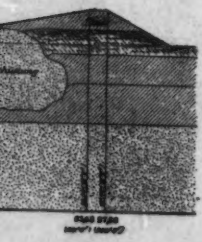
6. Km 9,000 links und Km 9,675 rechts. (Half cross-section at km 9,675.)

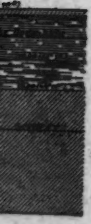


Km 10,500 links und Km 11,000 rechts. (Half cross-section at km 11,000.)

Fig. 8. Km 12,800.







Sanddammschüttungen im Moor.

Km 12,2-19,1.

Fig. 9. Ungewöhnliche Sanddammquerschnitte.

(Cross-sections of irregular sand-dams.)

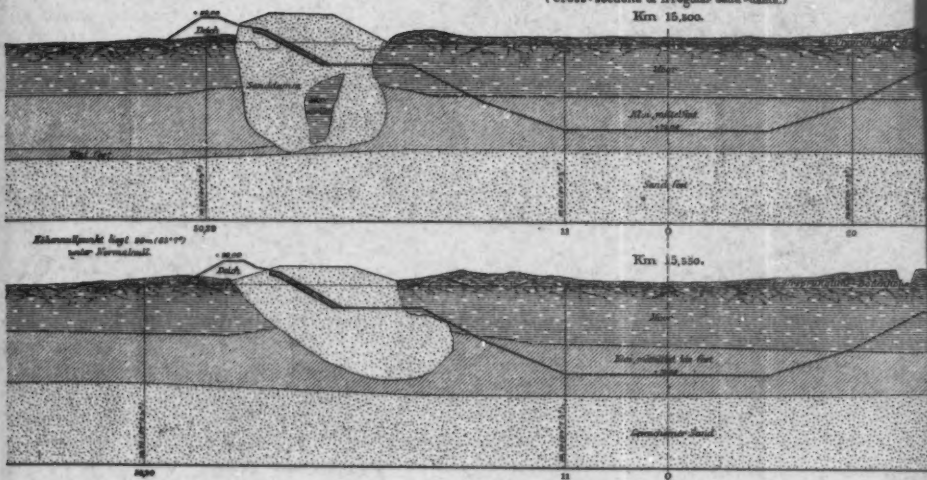
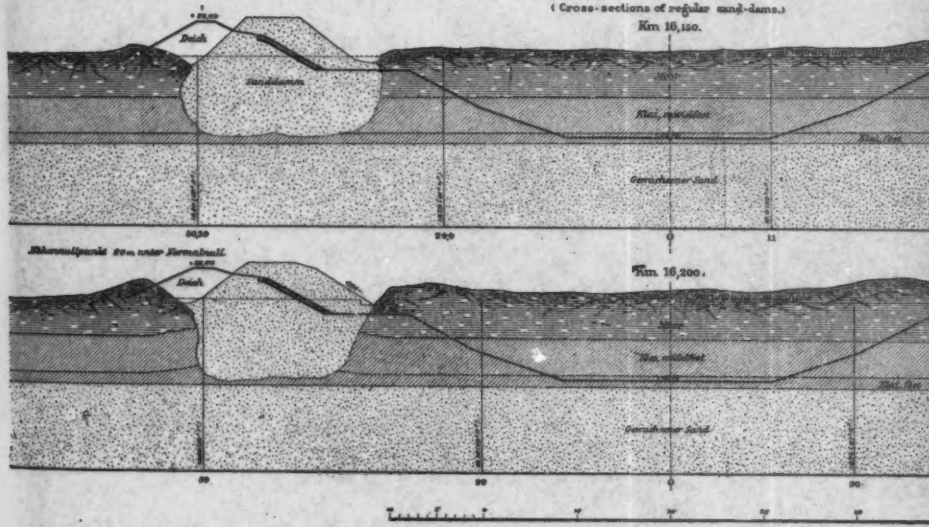


Fig. 10. Normale Sanddammquerschnitte.

(Cross-sections of regular sand-dams.)



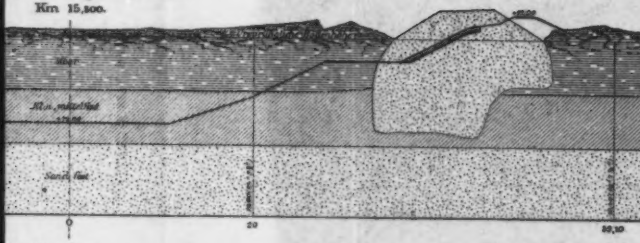
...schüttungen im Moor.

Km 13,2–19,1.

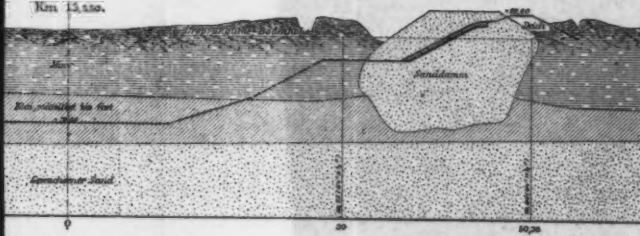
...öhnliche Sanddammquerschnitte.

...ections of irregular sand-dams.)

Km 15,300.



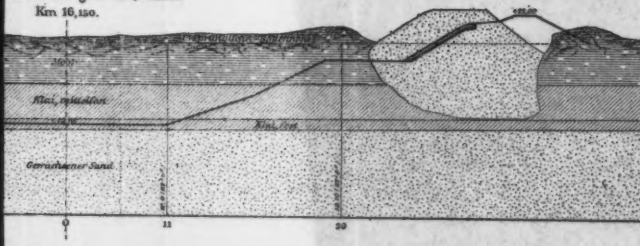
Km 15,150.



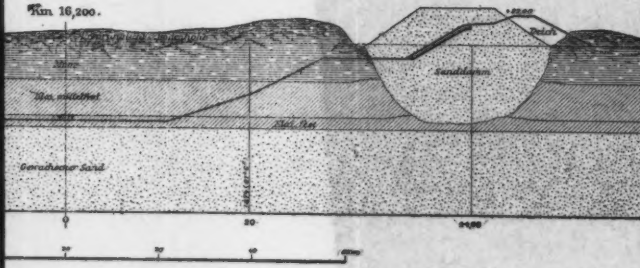
...male Sanddammquerschnitte.

...ections of regular sand-dams.)

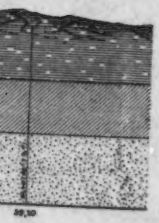
Km 16,150.

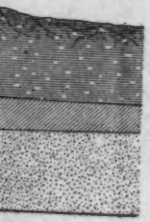


Km 16,200.



654.
V. ENGRS.
EAST SEA CANAL.





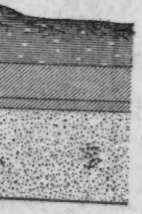


Fig. 11c. Querschnitt A-B.
(cross section A-B.)

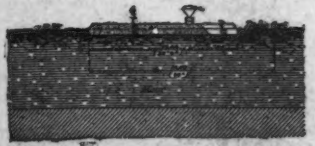


Fig. 11d. Querschnitt C-D.
(cross section C-D.)

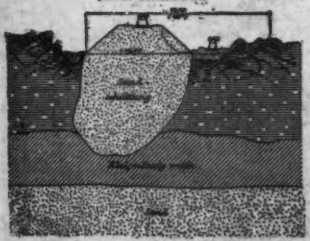


Fig. 11e. Querschnitt E-F des fertigen Sanddammes.
(cross section E-F of finished sand-dam.)

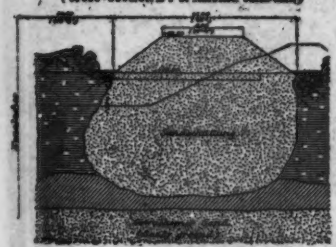
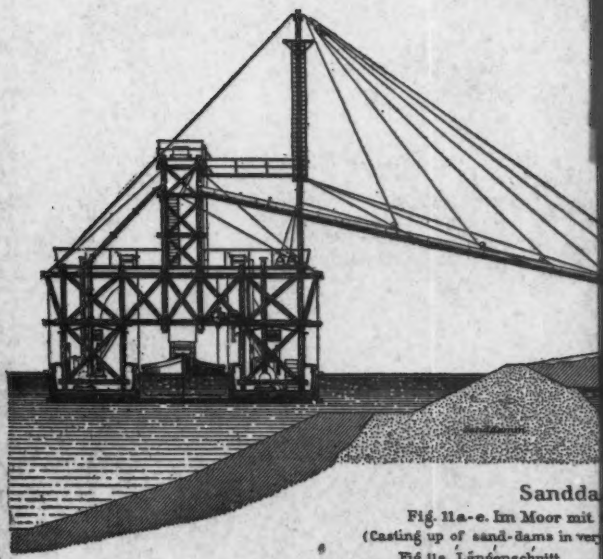


Fig. 11a. Querschnitt A-B.



Sandda

Fig. 11a.-e. Im Moor mit
(Casting up of sand-dams in ver

Fig. 11a. Längenschnitt.
(Longitudinal section.)

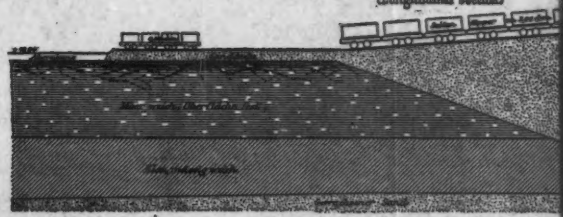
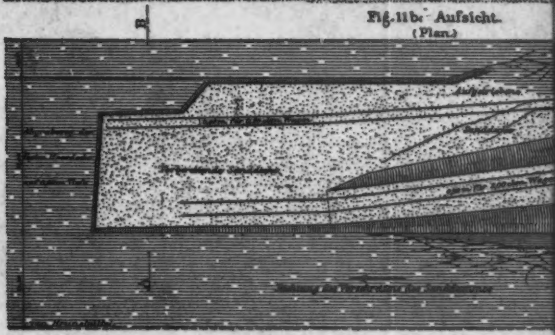


Fig. 11b. Aufsicht.
(Plan.)

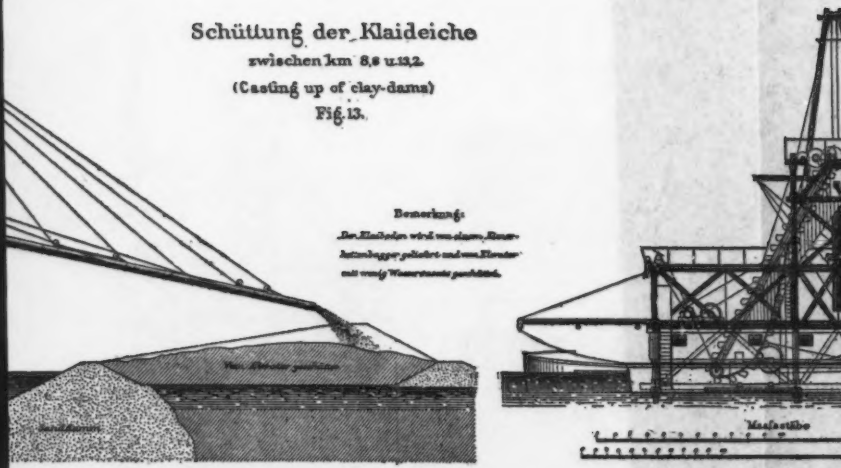


Schüttung der Klaideiche

zwischen km 8,8 u. 13,2.

(Casting up of clay-dams)

Fig. 13.



Sanddammschüttungen im Moor, km 13,1 - 19,1.

. 11a-e. Im Moor mit fester Decke.

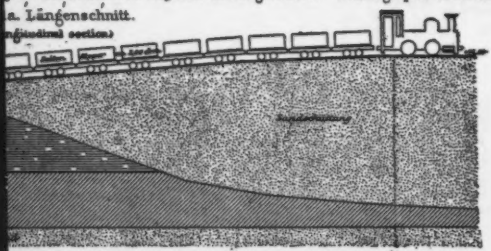
p of sand-dams in very soft moor grounds.)

Fig. 12a-e. In ganz weichem Moor

(Casting up of sand-dams in moor with settled upper-part.)

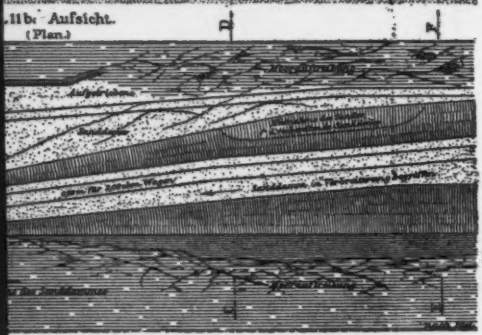
a. Längenschnitt.

ngitudinal section.)



. 11b. Aufsicht.

(Plan.)



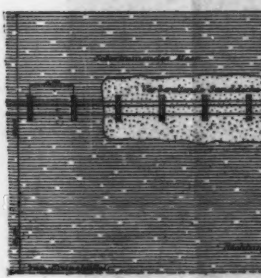


Fig. 12c. Querschnitt E-F des fertigen Sanddammes.

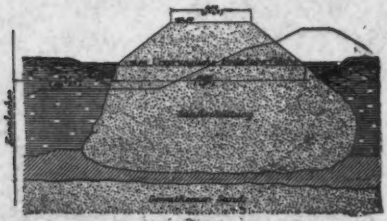
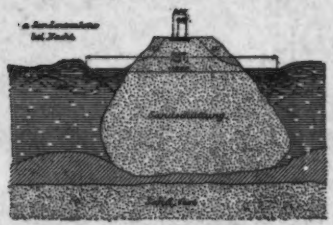


Fig. 12d. Querschnitt C-D.



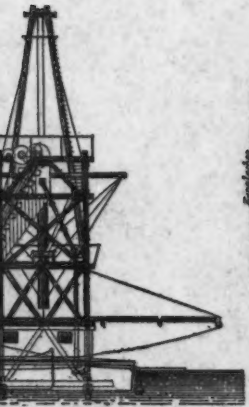


Fig. 12a. Längenschnitt.
(Longitudinal section.)

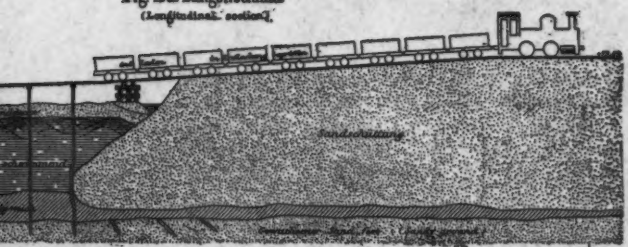
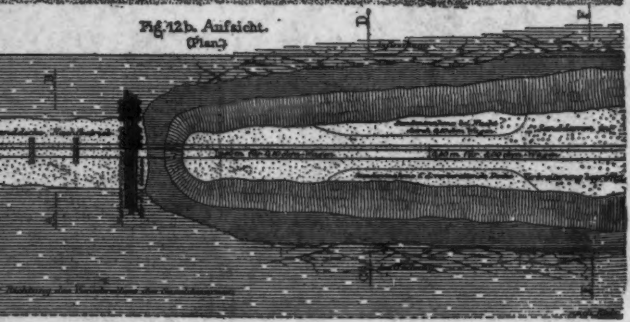


Fig. 12b. Aufsicht.
(Plan.)



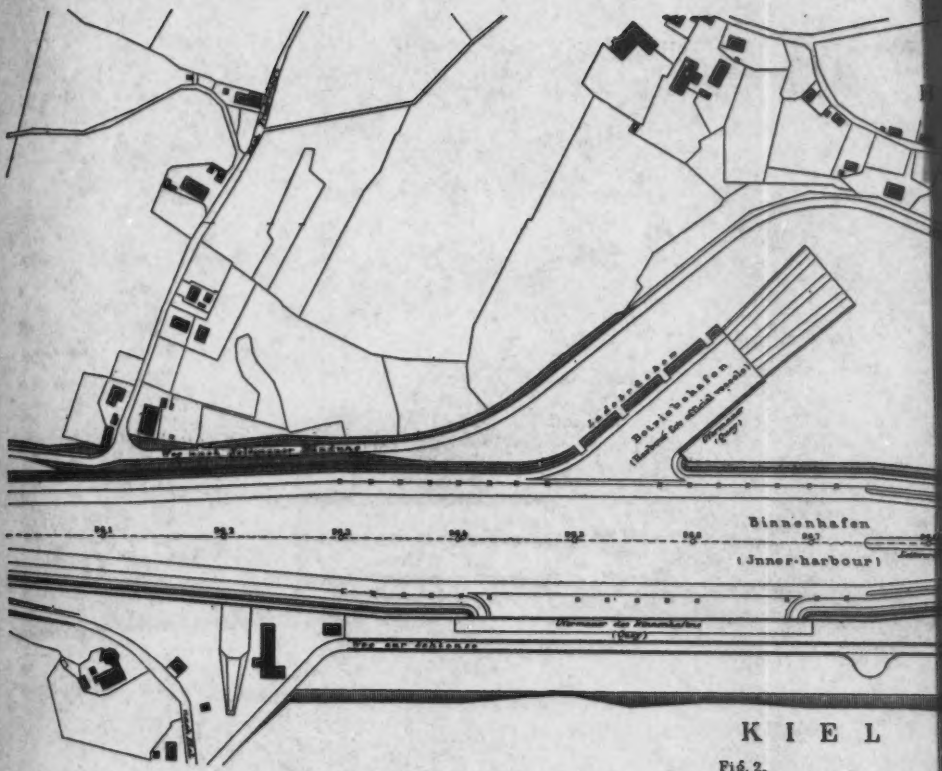

Betriebshafen
Binnenhafen
(Inner-harbour)
KIEL

Fig. 2.

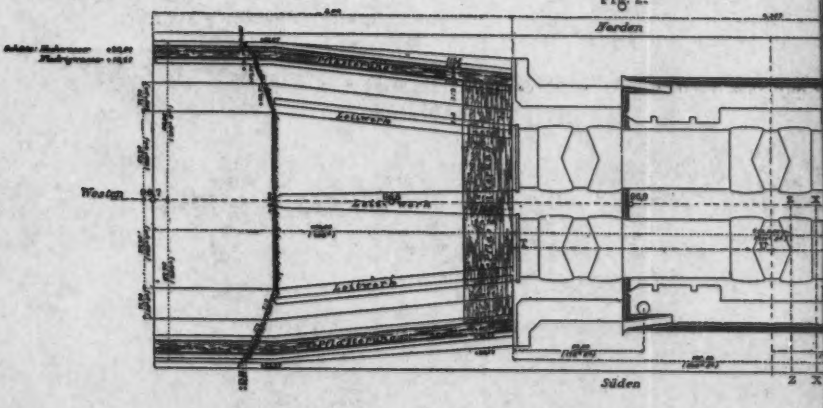
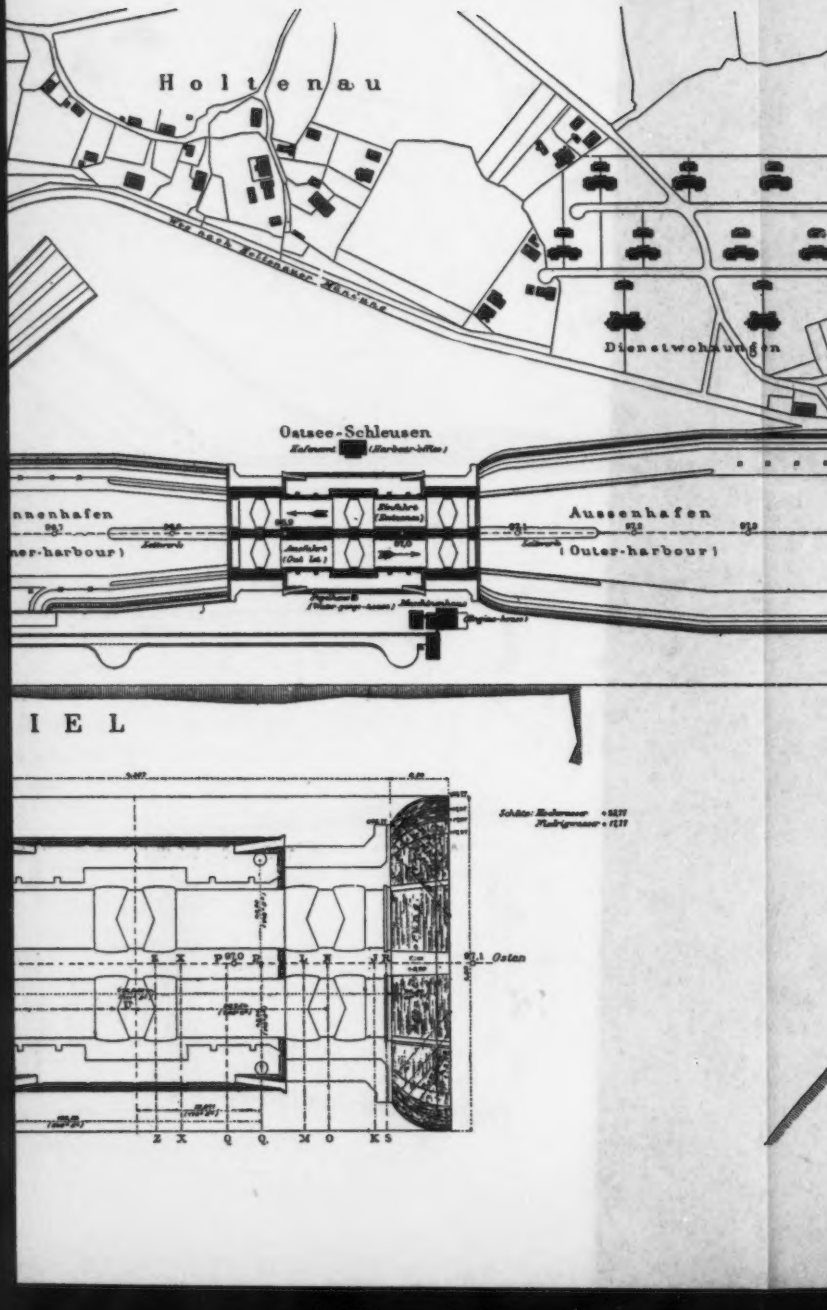
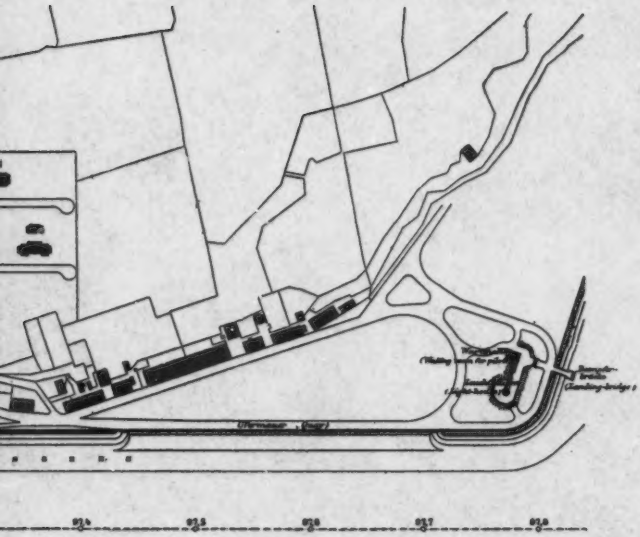
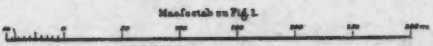

Norden
Süden

Fig. 1.


Holtenau
Dienstwohnungen
Ostsee-Schleusen
Aussenhafen
(Outer-harbour)
I E L



KIELER HAFEN



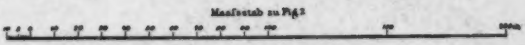


Fig. 3. Querschnitt
durch die Schifffahrtsthorkammer (Section) dur
(of the lockgate-chamber)

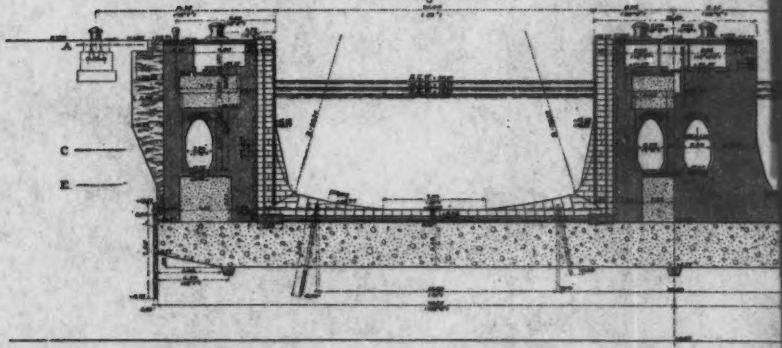


Fig. 4. Querschnitt durch die Schleusenkammer.

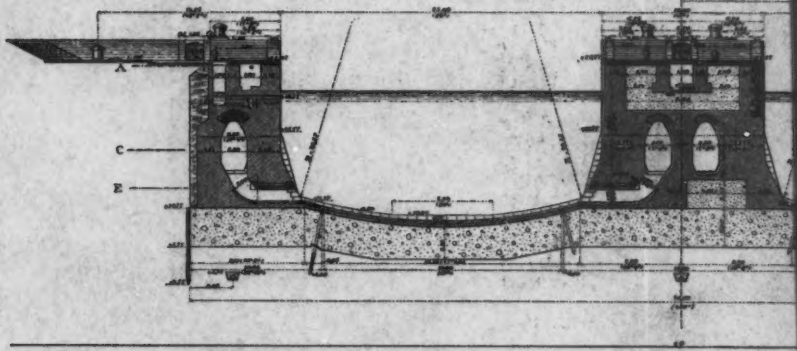
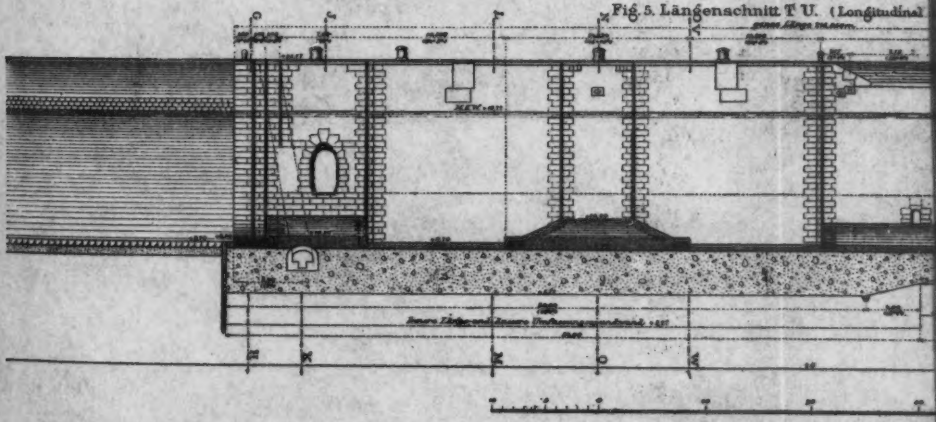
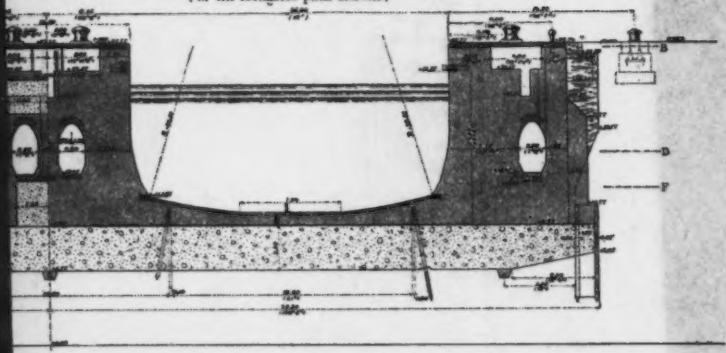


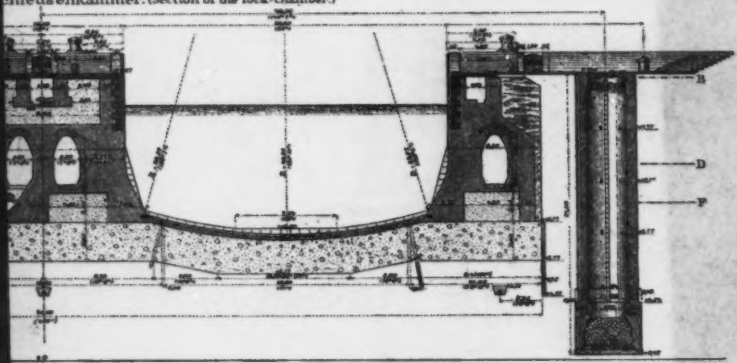
Fig. 5. Längenschnitt T U. (Longitudinal



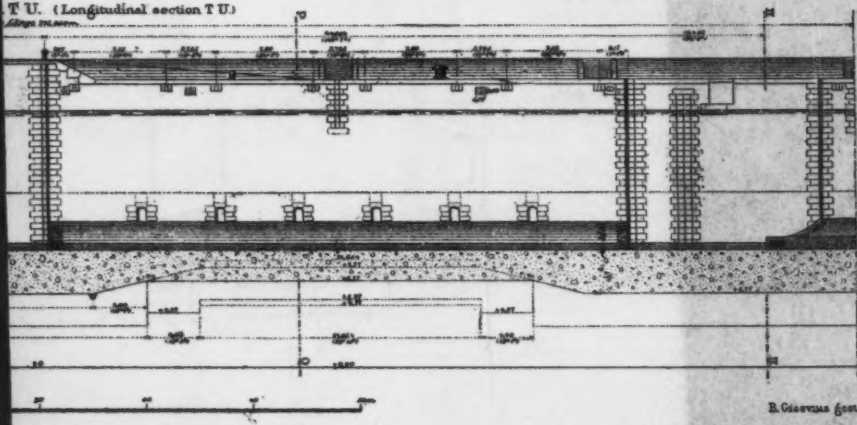
. Querschnitt
(Section) durch die Schifffahrtsthorpfeiler u. Drempel.
(of the lock-gates-pillar and sill.)



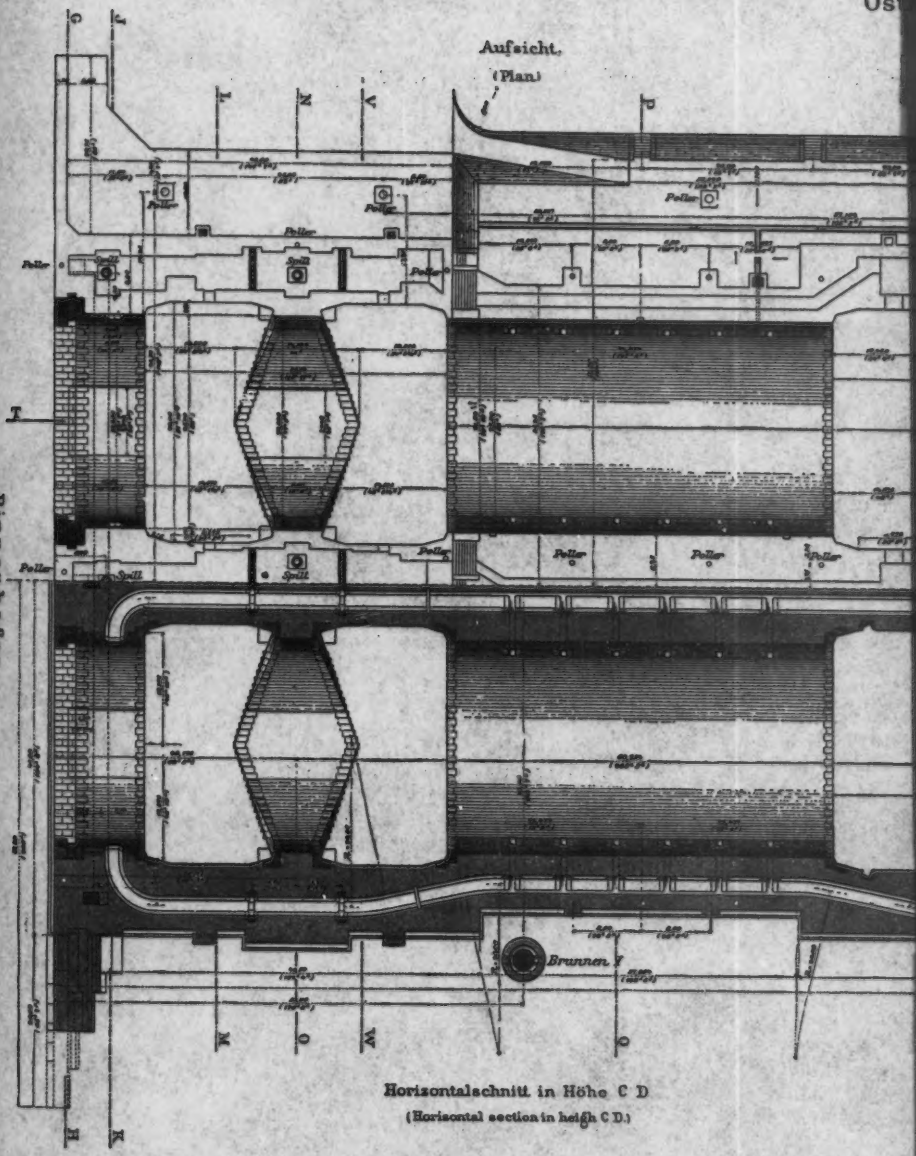
chleusenkammer. (Section of the lock-chamber.)



T U. (Longitudinal section T U.)



Binnenhafen.
(Inner-harbour.)



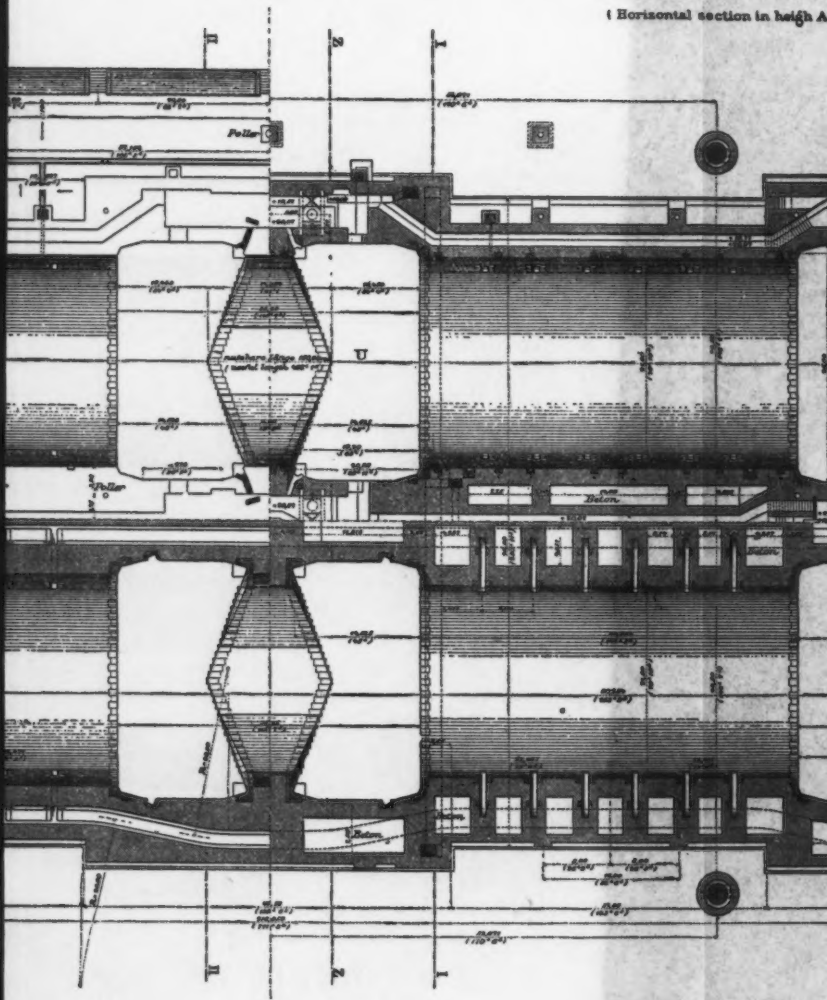
Horizontalschnitt in Höhe C D

(Horizontal section in heigh C D.)

Ostsee-Schleusen.

Fig. 6.

Horizontalschnitt in Höhe
(Horizontal section in heigh A



Horizontalschnitt in Höhe
(Horizontal section in heigh E

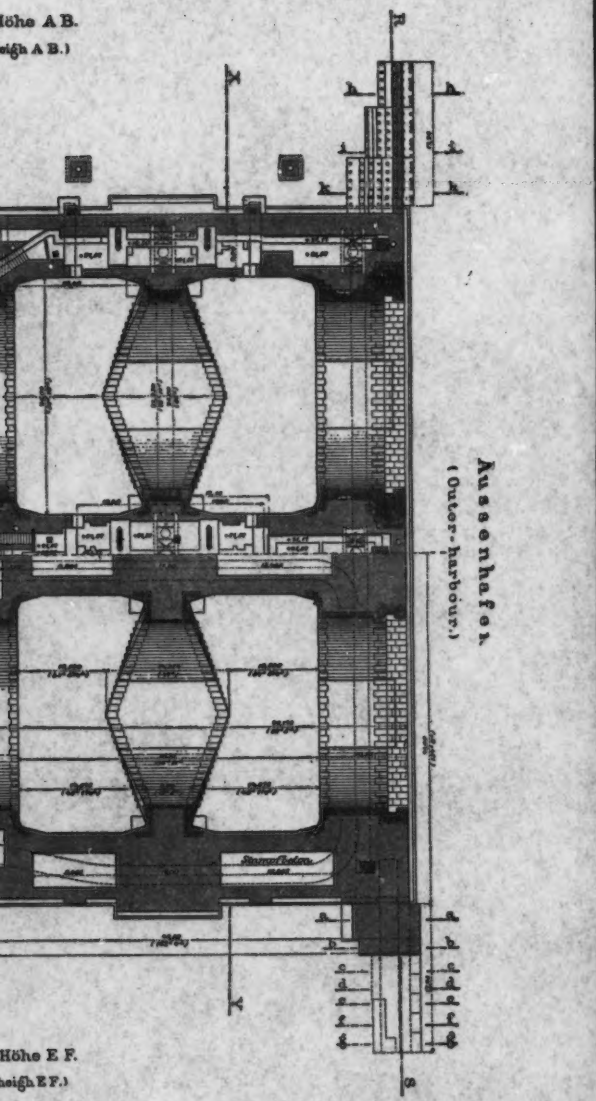
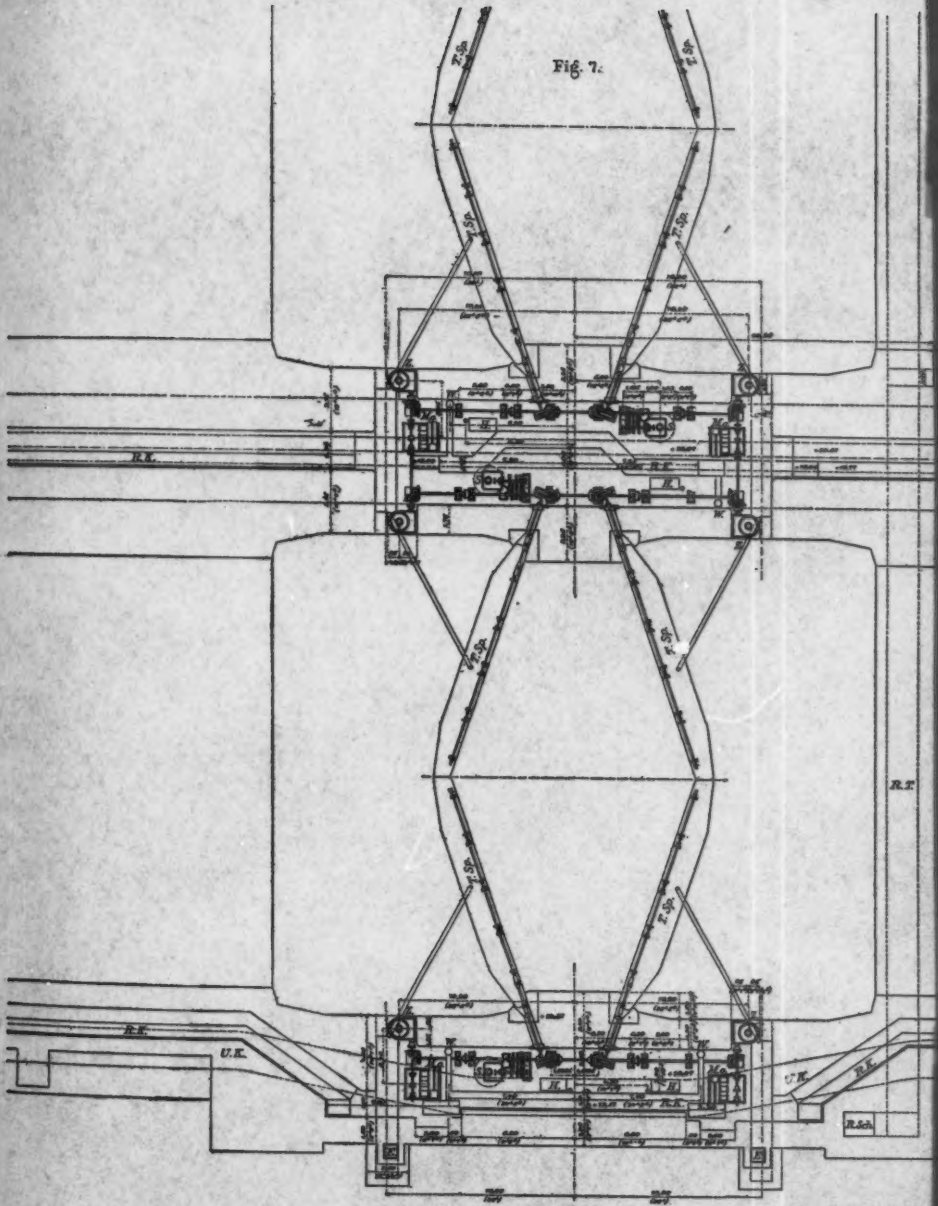
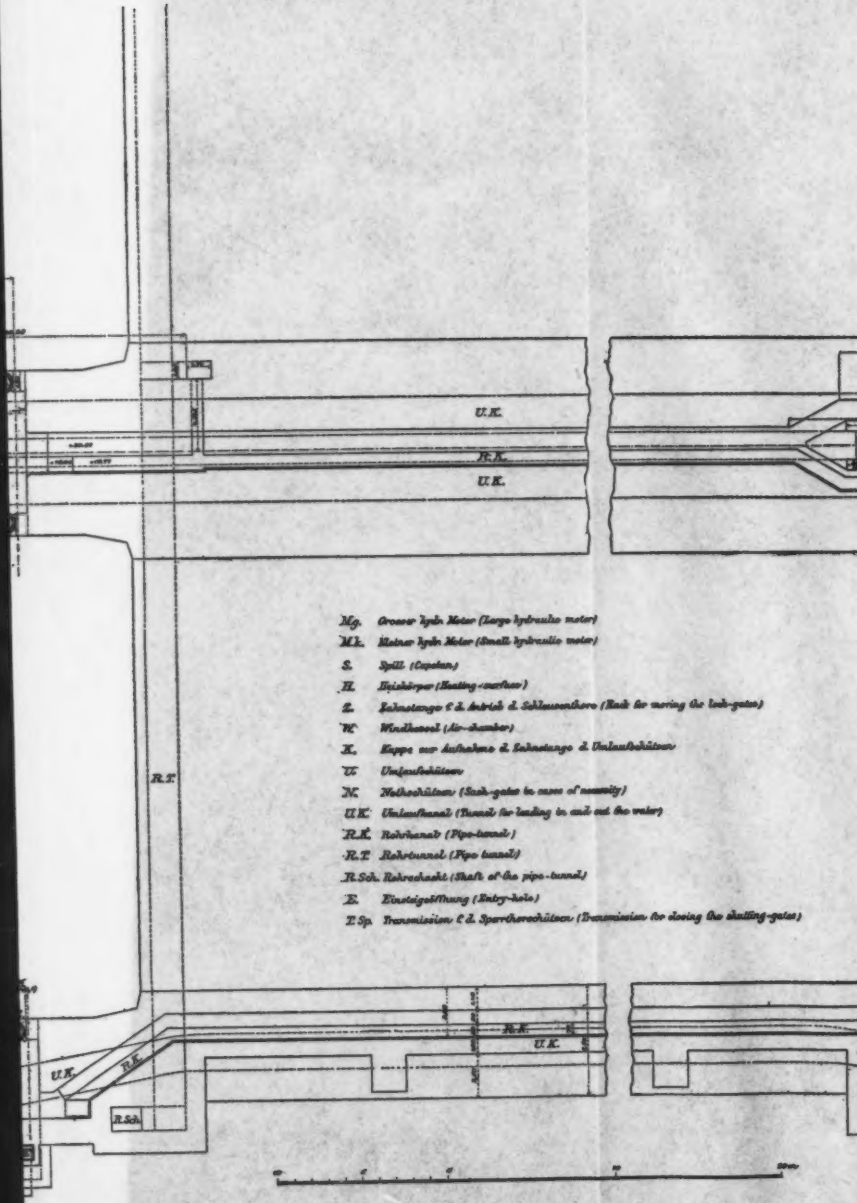

Höhe A B.
eigh A B.)
Aussenhafen.
(Outer harbour.)
Höhe E F.
eigh E F.)

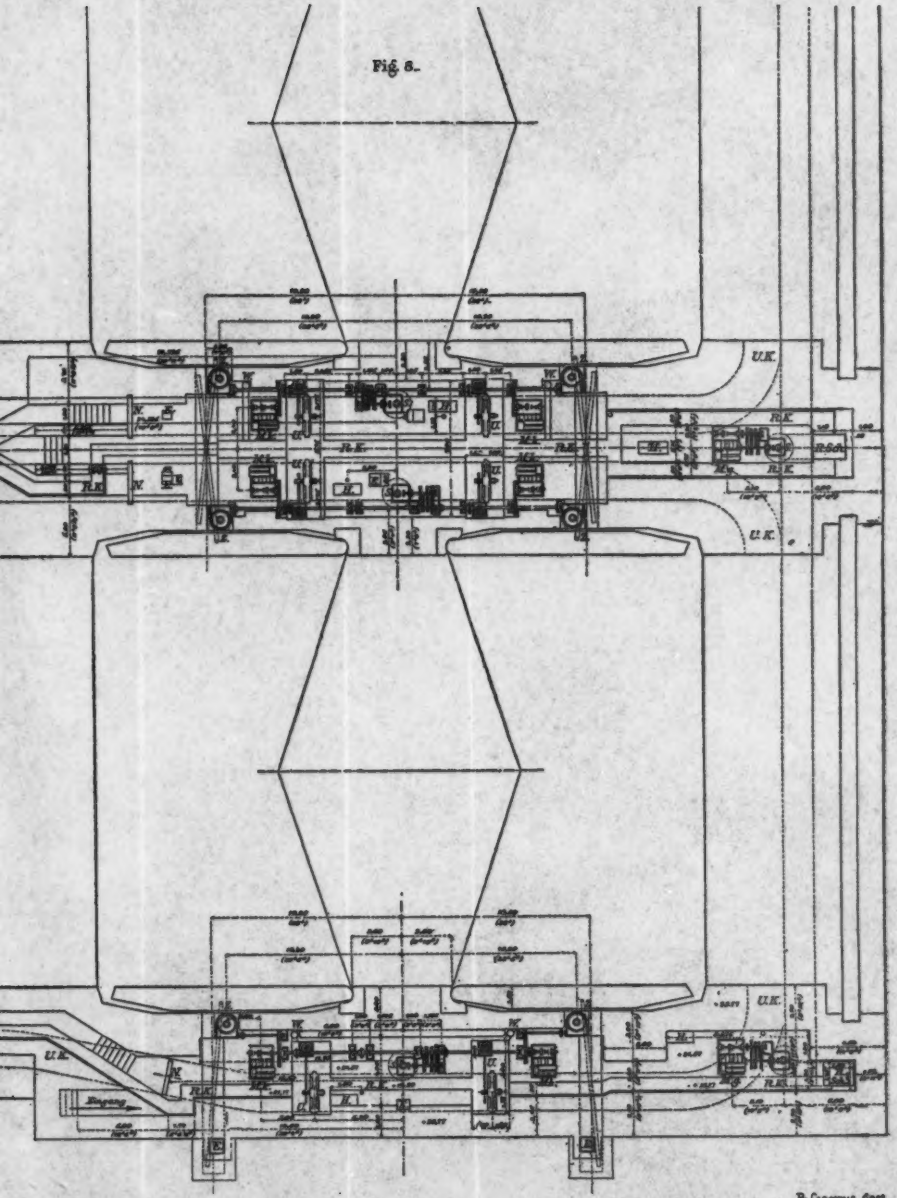
Fig. 7.





Mg. Grosser hydr. Motor (Large hydraulic motor)
Mk. Kleiner hydr. Motor (Small hydraulic motor)
S. Spill (Capstan)
H. Hebebock (Hoisting-anchor)
L. Zahnstange f. d. Antrieb d. Schlauenthore (Rack for moving the lock-gates)
W. Windkessel (Air-chamber)
K. Kappe zur Aufnahme d. Zahnstange d. Umlaufschützen
U. Umlaufschützen
N. Nothschützen (Lock-gates in case of necessity)
U.K. Umlaufkanal (Tunnel for leading in and out the water)
R.K. Rohrkanal (Pipe-tunnel)
R.T. Rohrtunnel (Pipe tunnel)
R.Sch. Rohrschacht (Shaft of the pipe-tunnel)
E. Einsteigöffnung (Entry-hole)
T.Sp. Transmission f. d. Sperrschützen (Transmission for closing the shutting-gates)

Fig. 6.


U.K.
U.K.
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7. *Cost of the East Sea Locks.*—The cost of the East Sea locks, exclusive of the approaches, will amount to about 9 000 000 marks.

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655.

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THE NEW RAILWAY STATIONS AT DRESDEN.

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Prepared for the International Engineering Congress of the Columbian Exposition, 1893.

The first railway in Saxony, and, at the same time, the first considerable railway in Germany, was that between Leipzig and Dresden, commenced in the year 1835, and opened for traffic in full length of 115 km., or 72 miles, in 1839. This railway has its terminus in Dresden-Neustadt, which, exclusively of enlargements, is still at the same place as 54 years ago. The station is situated on the right bank of the Elbe River, as marked by the letter *A* on Plate I.

The terminus of the second railway built in Saxony, from Dresden to Görlitz, which was opened for traffic in 1846, has its place also in Dresden-Neustadt, near to that of the Leipzig station, with which it was early connected by a siding for freight traffic. It is marked in the plan with *B*.

NOTE.—Discussions on all papers presented to the International Engineering Congress will be published simultaneously in the number for December, 1893.

The third line terminating at Dresden is the Saxon-Bohemian Railway to Prague and Vienna, completed in the year 1849 by the Saxon government, after it had been ceded by the company which had undertaken it. The terminus of this line is the Bohemian station, marked in the plan with *C*. A prolongation with a long viaduct and a bridge over the Elbe unites it to the stations *A* and *B* of the older lines in Dresden-Neustadt.

Another company constructed the short Albert-Bahn, named after the present King, then Crown Prince Albert of Saxony, from Dresden to Tharand, finished in 1854, with a terminus at *D* in the plan. It is now only a coal station, the passenger traffic, in consequence of the purchase and extension of the railway by the Government, having been transferred to the Bohemian station *C*.

Finally, in the year 1875, the railway Berlin-Dresden was finished by a company, with a terminus in Dresden-Friedrichstadt at *E* in the plan, and with a connecting track to the Bohemian station.

Thus there are now in Dresden four passenger stations. As to the freight stations, those of the lines ending at the points *A*, *B*, *D* and *E* of the plan are still in their original places, whereas the freight station of the Bohemian line, in the interest of the City of Dresden, wanting space for extension, has been transferred to the point *F*, between *C* and *D*. This new freight station *F*, with an inclination of 1 in 110 at its western end, was fitted also for sorting and shunting purposes, and provided with repair shops.

This multiplicity of railway stations, in a place of (1890) 305 000 inhabitants, lost its reason for existence in the same degree as the railways passed over into the management of the Government. After the acquisition of the lines to Görlitz, Bohemia (as far as Bodenbach) and to Tharand, the Government bought in 1876 the lines of the Leipzig and Dresden Company, and at last, in 1888, the Berlin and Dresden line from Dresden up to the limit of the kingdom. Several projects had formerly been made for a better connection of the Dresden stations, especially the passenger depots. But, after all the railways had become the property of the State, a total transformation of the railway system, including the freight stations, was planned. In addition, the river navigation on the Elbe and its growing importance for Dresden ripened the plan of a large river harbor, which necessarily had to be connected with the railways.

The problem to be solved was therefore:

First.—The erection of a central passenger station; for which the Bohemian station *C* in the plan was chosen.

Second.—The establishment of a central sorting or shunting station, which will be placed at *E* in the plan, by enlarging the Berlin station, near which also the river harbor will be excavated.

Third.—The connection of the passenger stations on the right bank of the Elbe at *B* in the plan, and their transformation into an intermediate station for all through trains of the Leipzig, Berlin and Görlitz lines (the passenger traffic for Berlin being transferred to the Leipzig line).

Fourth.—The combination of the freight stations in Dresden-Neustadt on the ground of the Leipzig station *A*.

Fifth.—The laying of sidings on a part of the freight station *F*, for storing and shunting passenger cars, and making up the passenger trains, and, in connection therewith, the erection of the necessary buildings for a central post-office.

Sixth.—The abolition of the level crossings.

As may be observed by looking at the plan, the passenger and freight traffics will be held entirely separate by passing the freight trains through the whole city without contact with the passenger tracks. All constructions for the passenger traffic are placed on the side towards the town, and those for the freight traffic on the outside. Instead of four shunting yards, as until now in use, between which the freight cars not intended for loading or unloading at the arrival station must be carried to and fro, there will be common sorting and shunting yard combined, with a large repairing establishment, at *E* in the plan. Here all the freight trains, including those from the local freight stations of Dresden, will be received. For this purpose there are planned at *a* 17 entering sidings of 600 m. (2 000 ft.) in length for receiving trains numbering 75 cars. The access to these sidings is nearly independent for all the different railway lines, and four freight trains may enter at the same time. After entering, the engine as well as the trainmen leave the train, and the papers relating to the contents are taken to an office in the immediate neighborhood, where they are separated according to the destinations of the various cars. After the arrival of a train, a shunting engine moves the cars on a double-track railway, laid with an inclination of 1 in 80 to the

group *b*, of five inclined sidings, which converge into an end siding, by which the shunting engine leaves the train, to pull up a new one. The whole sorting station forms an inclined embankment of 17 m. (57 ft.) greatest height, filled up with the material gained from the river harbor, about 1 500 000 cu. m. As the uniform inclination of the sorting sidings is 1 in 100, the freight cars run by gravity, and experience has shown that this inclination is sufficient, even during strong contrary winds. Out of the group of inclined sidings *b*, the cars run either single or in groups, having the same destination, into the sorting sidings, where they are stopped by brake-blocks laid on the rails. There are 30 parallel sorting sidings (*c* in the plan), of which every one receives the cars for a particular direction, be it in Dresden itself or outward on the lines. Now it remains to arrange the cars destined for the intermediate stations in the succession necessary for avoiding all subsequent shunting. This is done by using the so-called gridirons (*d* in the plan), harp-shaped groups of sidings. In the upper gridiron, with eight parallel sidings, eight groups of cars can be formed, and in the second gridiron below the former, with four parallel sidings, every group may be separated into four parts, so that it is possible to divide a train in $4 \times 8 = 32$ different manners, by letting them move in proper succession after one another. For the freight trains starting from Dresden, there are no more than 16 different destinations of the freight cars, and ordinarily only eight different stations come into consideration, so that the arranging of a train according to the succession of the stations can be finished in the first gridiron. Nor is this number exceeded by the branches to the different freight houses, mills and other loading places passed by the local trains in Dresden. After passing the gridirons, the cars run into the departure sidings *e*, where they are coupled. These sidings are 14 in number, and near to them are placed the engine houses, so that after being manned and furnished with the necessary papers from the office, to which they had been taken, the train may leave the station, and this departure can be effected in four different directions at the same time. The cars wanting repairs are moved from group *c* into special sidings, from which they are conveyed to the repairing shops at *f* of the plan.

The length of the sorting yard is 2 500 m. (8 300 ft.); its breadth, including the workshops, is 600 m. (2 000 ft.). There are 51 000 m. (170 000 ft.) of tracks and sidings. As the plan shows, there is still

room for a considerable enlargement of the works now in course of construction.

The freight stations are marked in the plan by the letters *A*, *D*, *F*, *G*, *H* and *I*; they are all in direct connection with the sorting yard, the construction of which was begun in the year 1891, and will probably be opened for traffic in the month of May, 1894.

The sorting by gravity has been practiced many years in Saxony, and a publication on this method of arranging the cars in the "Organ für Eisenbahnwesen," 1871, page 60, has helped to give an impulse to its extension over Germany. In England Mr. Footner has introduced the gridirons, invented by him, on the shunting station at Edgehill, near Liverpool, as is described in the "Working and Management of an English Railway," by George Findlay, London, 1889, under the chapter of "The Shunting and Marshalling of Goods Trains."

The investigations made by a commission of officers of German railways have shown that the arranging by inclined sidings requires no more than half the time and cost of the ordinary shunting by the locomotive, and besides causing less damage to men, to cars and to the goods conveyed, this proceeding needs the least extension of the sorting station. The use of gravity was formerly limited either to separating the cars for the different destinations, or to collect them on the departure siding, one-half of the work—commonly the collecting —being always done on level sidings by the locomotive. The invention of Mr. Footner doubles the profits of the working by gravity, as it unites both the separation and the combination of the cars. The new sorting yard at Dresden will be the first application of Mr. Footner's method in Germany.

The chief advantage of the concentration of all the shunting and marshalling works of a large center of commerce is the quick dispatch of arriving freight trains. Though the movement of cars between some of the local freight stations and the sorting yard will be multiplied, the saving gained by the quick expedition in the transit of cars overbalances that little disadvantage.

At Dresden the number of cars to be shunted daily is about 3 000; but the new yard is large enough for arranging 4 000 cars, and, after the possible extensions, the number of cars to be moved may be still greater. In the neighborhood of the sorting yard there are large tracts of land for building purposes, and especially the area between

the yard and the river harbor, owned by the Government, offers an opportunity for erecting industrial establishments with branch lines.

The establishments for the passenger traffic are with reference to the plan :

First.—The central passenger station *C*.

Second.—The terminal station *L*.

Third.—The passenger stations at Neustadt *B*, at Friedrichstadt *E*, and Wettin Strasse *K*, the latter two serving chiefly for the city and suburban traffic, for which other stopping-places may be erected in the future at *M* and *N*.

The central station *C* has a very suitable position, lying at a distance of only 1 km. from the center of the city. After the open grounds fit for buildings are covered, this station will be situated in the midst of the Altstadt or the earlier part of the city, on the left bank of the river. For the Neustadt, on the right bank, the station *B* will be well accommodated to the passenger traffic.

At the central station *C*, the tracks and platforms will be built on two levels, differing by 4.4 m. (14 ft. 5 ins.). For the east and west line, Görlitz-Dresden-Chemnitz, the central station will be used as a "pocket-station," ending before Prager Strasse, the first street crossed at present on the level by railway tracks. Now, as the tracks will be cut off before reaching that street, it is not necessary to elevate them; but the elevation is required for the tracks passing beyond the station, in order to abolish the level crossings of Prager Strasse, as well as of a number of other streets on the southern side of it in the direction to Bodenbach and Prague. Thus to the passengers using the six pocket-station tracks—about one-half of all—the mounting of stairs will be spared.

The central station will be connected by sidings with the terminal station *L*, at which all passenger trains, excepting the through trains, are to begin and end their movements. Therefore, this latter station will afford ample conveniences for the making-up of trains and for sheltering of engines; also, for the despatch of parcel goods and of the whole railway business of the post-office.

The passenger stations *K*, *B* and *E* will only have intermediate traffic in connection with the central station. The tracks and sidings of these stations are either above (*B* and *K*) or below (*E*) the public streets, and are therefore accessible only by stairs.

The following is a synopsis of the areas and length of tracks and sidings of the new stations:

	Square meters.	Meters of track.
1. Central station *C*.	180 000	23 000
2. Terminal station *L*.	200 000	23 000
3. Intermediate station, Wettin Strasse *K*.	25 000	1 500
4. Intermediate station, Friedrichstadt *E*.	15 000	1 500
5. Station Neustadt *B*.	130 000	18 000
Total for passenger traffic.	550 000	67 000

	Square meters.	Meters of track.
6. The sorting and shunting yard *H* has an area of	750 000	98 000
7. Freight station, Altstadt, *F*	135 000	15 000
8. Coal station *D*.	95 000	11 000
9. Freight station, Neustadt, *A* and *I*.	310 000	31 000
10. Station at the harbor *G*.	200 000	19 500
11. Old quays on the river at *O* and *P* of the plan	90 000	8 500
Total for freight traffic.	1 580 000	183 000

The sum of the areas adapted to the railway traffic of Dresden will, therefore, be 158 + 55 = 213 hectares (about 500 acres), and the length of tracks, about 250 km. or 155 miles. As the area of the city is 2 858 hectares, the railways will occupy more than 7% of it.

The new Railway Stations in Dresden.
Pieschen
Wilder-
Mann.
Mickten
Übigau
Verkehrs- und Winter-Hafen
Rangir-
Bahnhof
Bahnhof
Bahnhof
Güter
Dresden

Bahnhof
Erweiterung der Güterbahnhöfe
Bahnhof
Bahnhof